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A NOVEL LEARNING-BASED LOCATION MANAGEMENT SCHEME

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Ce mémoire intitulé:

A NOVEL LEARNING-BASED
LOCATION MANAGEMENT SCHEME

présenté par YU Qian-Ning
en vue de l'obtention du diplôme de: Maîtrise ès sciences appliquées
a été dûment accepté par le jury d'examen constitué de:

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RESUMÉ

Dans les systèmes sans fil de la télécommunication 3G, les réseaux mobiles devront soutenir une grande population des utilisateurs mobiles et doivent fournir des services efficaces et peu coûteux sous des caractéristiques diversifiées d'architecture de réseaux, des services, et des types d'utilisateur. Une des questions les plus importantes dans les réseaux mobiles est la gestion de localisation, qui inclut deux procédés, la mise à jour de localisation et la recherche de localisation. Ces deux procédures encourront le trafic de signalisation dans les réseaux sans fil. Alors, un algorithme optimal est exigé, c.-à-d., appel conduit avec la contrainte permise de temps et moins d'échange de l'information.

Nous avons proposé ici un arrangement apprendre-basé de prévision d'endroit pour localiser un utilisateur mobile (MU). Il est conçu pour prévoir le futur mouvement d'un utilisateur mobile. Dans notre approche, en utilisant un graphique d'étude, le système apprendra le comportement quotidien de l'utilisateur en observant et en recodant les mouvements de l'utilisateur. Les ensembles de date étant obtenu de l'apprentissage, nous formerons le réseau pour obtenir la plupart de probabilité pour le prochain secteur d'endroit dans une liste. Et alors nous pouvons induire une liste séquentielle des endroits le plus susceptibles où chaque utilisateur est localisé.

Un ensemble d'expériences est conçu pour évaluer la performance de cet algorithme. Les résultats de simulation prouvent que le nouvel algorithme de gestion de localisation réduit la surcharge de trafic de signalisation du réseau et la consommation d'énergie. Il améliore également le débit moyen du réseau. Tous ceux-ci sont implémentés sans augmenter le délai moyen du réseau.

ABSTRACT

In 3G wireless telecommunication systems, the mobile networks will have to support large population of mobile users and have to provide efficient and low-cost services under diversified characteristics of network architecture, services, and user types. One of the most important issues in the mobile networks is the location management, which includes two procedure, location updating and search. Both of them will incur signaling traffic in the wireless networks. An optimal algorithm is required, that is, call routed with allowable time constraint and less information exchange.

We proposed here a learning-based location prediction scheme for locating a mobile User (MU), which depends on its movement pattern. In this scheme predicts and builds a user profile and focuses on producing and maintaining the list of the user profile, as well as improving its performance to prediction mobile movement can be designed to predict the future movement of a mobile user. In our approach, using a learning graph, the system will learn the user's daily behavior by observing and recoding the movements of the user. With the date sets got from the learning process, we will train the network to get a most probability for the next location area in a list. And then we can induce a sequential list of the most likely places where each user is located.

A set of experiments is designed to evaluate the algorithm's performance. Simulation results show that the novel location management algorithm successfully reduces the network overheads and the power consumption. It also improves network average throughput. All these achievements are at no expense of other performances.

CONDENSÉ EN FRANÇAIS

1. INTRODUCTION

Un des problèmes les plus importants et les plus provocants pour 3G est la gestion de mobilité qui permet à des réseaux de télécommunication de localiser des terminaux mobiles pour la livraison d'appel et de maintenir des connexions quand ils entrent dans une nouvelle cellule. Ainsi, la gestion de mobilité soutient les terminaux mobiles, et permet à des utilisateurs mobiles se déplace tout en simultanément leur offrant des appels entrant et soutenant des appels en cours. Un aspect principal dans la gestion de mobilité est gestion de localisation.

La gestion d'endroit joue un rôle central en fournissant aux réseaux mobiles sans fil omniprésents de services de communications à l'avenir. Dans l'ensemble, les deux procédures fondamentaux qui comportent la base de la gestion de localisation sont la mises à jour de localisation et la pagination (la recherche de localisation). La mise à jour de localisation est lancée par une station mobile, et informe le réseau du secteur courant de l'endroit de l'abonné. La recherche est lancée par le réseau quand un appel entrant arrive. Les messages de pagination sont émis dans un ou plusieurs secteurs de pagination, incluant le secteur courant, et informent l'utilisateur cible de l'appel entrant.

2. PROBLÈMATIQUE

Dans les troisième systèmes mobiles de télécommunication de la génération (3G), la quantité du trafic de signalisation due à la gestion de mobilité augmentera de manière significative en raison du volume de montée des abonnés et de la demande pour des taux plus élevés de transmission. Pour satisfaire la demande, différents algorithmes de gestion de mobilité doivent être mis en application selon le processus de la mobilité de l'utilisateur. Les exigences changeantes vis-à-vis de la gestion de mobilité changeront des méthodes de maintenir et de traiter les données de la mobilité de l'utilisateur. Un objectif principal de futures activités de recherches est de réduire au minimum le trafic de signalisation. Il est évident que les techniques d'optimisation et les algorithmes efficaces de gestion d'endroit soient les issues critiques, au sujet de l'exécution 3Gs globale. Le critère pour évaluer l'optimum dépend fortement du genre de comportement d'utilisateur.

3. OBJECTIFS DE RECHERCHE

À la différence des problèmes de gestion de ressource dans les réseaux cellulaires, le problème de gestion de localisation est orienté utilisateur par définition. Naturellement, il serait sage d'utiliser la mobilité personnelle et le profil d'appeler de différents abonnés pour l'optimisation. Les techniques de mise à jour et de pagination devraient être détail d'utilisateur pour ajouter le contact personnel au service personnel de communication. La représentation de la connaissance et l'apprentissage du profil d'utilisateur sont ainsi deux facteurs principaux.

4. REVUE DE LITTÉRATURE

Ce qui suit sont quelques méthodes de gestion de localisation pour le système de communication de la troisième génération, qui sont divisées en trois groupes principaux : statique, dynamique et intelligent.

Les algorithmes statiques

Pour la mise à jour statique de localisations, la méthode classique qui est appliquée largement dans les réseaux courants emploie des secteurs larges fixes et de réseau d'endroit. Tous les abonnés ont les mêmes frontières de cellules pour envoyer l'endroit mettant à jour des messages. Cela mène à un trafic de signalisation éclaté sur les canaux de signalisation des cellules qui sont sur la frontière de secteur d'endroit, tandis que d'autres cellules ont les canaux contrôle vide.

Pour les approches statiques, la mise à jour de positions se produisent toujours quand un utilisateur passe à la frontière d'un LA (Secteur de Localisation) ou de cellules. Elles peuvent être inefficaces parce qu'elles sont communes à tous les utilisateurs, et les cellules proches de la frontière tendent à avoir un trafic plus élevé de mise à jour d'endroit. Les exemples sont *Partitioning* et *Reporting cell.*

Des algorithmes dynamiques

Dynamiques sont basés sur des statistiques pour refléter le comportement de mobilité d'un MU, par exemple, il souligne la capacité du réseau. Pour la plupart de ce genre d'algorithmes, la mise à jour est basée sur le pattern individuel de mobilité d'utilisateur. Ils réduisent certain coût de la mise à jour. Certains exemples sont comme suit :

- Time-based
- Distance-based
- Movement-based
- State-based

Mais pour les méthodes dynamiques, le délai de paginant n'est pas contraint. Le temps requis pour localiser un MU est directement proportionnel à la distance depuis la dernière mise à jour.

Des méthodes intelligentes

De mise à jour et de pagination d'endroit d'algorithmes intelligents ont été employées pour résoudre un éventail de problèmes complexes ces derniers temps. Ces algorithmes ont énormement contribué aux arrangements de gestion d'endroit. La majeure partie d'exister travaille sur ces algorithmes basés sur le profil d'utilisateur, la mise à jour dépend de l'appel d'utilisateur et du modèle de mobilité. Certains exemples aiment,

- Location Prediction
- LeZi Update
- Profile-based
- Adaptive Fuzzy Inference Approach

Mais les méthodes existantes, dans de l'ampleur, ont toujours leurs limitations à différents aspects.

5. SOLUTION PROPOSÉE

Comme observation et étude, le comportement d'une personne est tout à fait régulier, comme nous savons des enquêtes de trafic de route et de la théorie de la circulation. En utilisant des méthodes de théorie du trafic de route, ce comportement de régularité peut être modelé avec des activités en tant que des activités disponibles de temps "à la maison", "travail" telles que "sport" et chemins résultants (par exemple manières) entre eux. Ces aperçus ont prouvé que le comportement géographique est tout à fait stable dans le sens des activités répétées au même endroit. Mais le rythme dans le sens de répéter des activités en même temps des jours de chaque n n'est pas aussi stable. Pour une personne typique, 2-4 activités couvrent 75% et 8 activités couvrent 85% de tous les mouvements observés plus de quatre semaines.

Avec le respect cette régularité, nous avons développé un facile efficace et la méthode puissante, qui permet à un futur plus de prévision du chemin du mouvement de l'utilisateur sur les profils d'utilisateur s'est produite par la méthode ci-dessus. Tous les points géographiques (par exemple à la maison et travail) le long d'un itinéraire seront seront stockés comme chemin dans le profil d'utilisateur. L'arrangement proposé, à savoir algorithme de Matrix de prévision (PMA), bases sur la théorie des probabilités et étude intelligente. Elle appartient également au type profil-basé, en outre nous ajoutons les facteurs intelligents, en apprenant les rapports entre le comportement de mouvement d'utilisateur et le profil d'utilisateur mobiles pour que le but prévoie les futurs endroits.

L'arrangement pour la prévision mobile de mouvement est basé sur l'histoire du mouvement de l'utilisateur mobile (MU), qui a été enregistré pour certaine durée de temps, appelé l'histoire d'User Movement (UMH). Cette méthode est appliquée avec un graphique d'étude et une matrice de prévision. Dans cette méthode, nous alimentons les données de formation d'UMH à un arbre d'étude, dans lequel les noeuds présentent les cellules auxquelles MU ira à au temps différent, et les lignes représentent un chemin que MU vont pendant un jour sur l'observation. L'arbre est un graphique pesé, et le poids représente la probabilité au prochain noeud. Après que la pain-première recherche dans l'arbre nous obtiennent le meilleur gain, c'est la plupart de chemin de possibilité pour le MU en question. Et alors le résultat sera employé pour produire de la prévision Matrix. Les éléments dans le PMA sont présentés comme une probabilité à un moment donné pour un MU d'une cellule à la prochaine cellule. Enfin après une certaine opération de Matrix, nous obtiendrons le bon état du MU, qui est le profil d'utilisateur.

Dans cette méthode, avec un graphique pesé, après qu'une souffle-première recherche dans l'arbre nous obtiennent le meilleur gain, qui est la plupart de chemin de possibilité pour ce MU. Et alors le résultat sera employé pour produire de la prévision Matrix, dans laquelle, les présents d'éléments une probabilité à un moment donné pour un MU d'une cellule à l'autre. Enfin après une certaine opération de Matrix, nous obtiendrons les bons états du MU.

Nous définissons une matrice de probabilité $M_k(p,\ t_k)$, représente la probabilité que le MU transférera à partir des états S_k à S_{k+1} au temps t_k. Et le p_{ij}, la valeur du M_k, représente la probabilité du transfert de MU à partir de la cellule i à la cellule j, à ce moment-là. Nous définissons la matrice $M_k\ (p,\ t_k)$, de probabilité, puis pour la rangée i, la colonne j, l'élément dans la matrice, p_{ij}, présents une probabilité de la cellule i à la cellule j au T_i de temps.

Ainsi donné l'endroit courant $(L_k,\ t_k)$ et T, le problème de la prévision d'endroit est d'estimer l'endroit L_{k+1} au temps t_{k+1} ou t_{k+T}.. Pour estimer la possibilité de l'état donné à un futur temps, nous pouvons donner un vecteur d'état s, $s = s[n\ ]$, où n est le nombre de cellules dans un town/city. Il présente l'état actuel d'un abonné à un moment donné période. Et la valeur des éléments dans S est 0 ou 1, 1 pour dans la cellule, alors que 0 pour pas dedans la cellule. Dans notre modèle, nous avons seulement 9 cellules en question, ainsi nous définissons 9 éléments dans la rangée de vecteur.

S'accordant au principium exposé ci-dessus, nous obtenons chaque état pour chaque durée de temps, ceux sommes les endroits prédictifs, les cellules en lesquelles le résidant mobile de volonté de borne. Rassemblez toutes ces cellules pour l'abonné dans l'ordre de temps, puis une table sort, qui est son chemin de cheminement pendant la période de temps d'observation. Enfin l'ensemble des états sera le profil de la borne mobile, aussi le chemin de cheminement.

Avec ce profil d'utilisateur, nous pouvons obtenir une prévision d'endroit sur l'abonné. Et beaucoup de méthodes basées sur le profil d'utilisateur obtiendront une bonne exécution en réduisant le coût de mise à jour et de pagination d'endroit, qui est notre objectif commun sur les réseaux de télécommunication sans fil de 3G.

6. MODÈLE DE SIMULATION

Notre topologie de simulation modèle une ville tracée dans un secteur de $10000 \times 10000 m^2$. La ville est divisée en 100 cellules. Les utilisateurs mobiles peuvent se déplacer dans et entre les cellules. Comme prétention, les personnes de la ville sont toute la vie dans le secteur de l'assurance par radio. Il y a résidence, bureaux, centres commerciaux, hôpitaux, écoles, et ainsi de suite. Tous les résidants peuvent trouver chaque chose qu'ils ont besoin, par conséquent ils vivent seulement dans la ville et ne partent jamais. Tout le monde dans la ville a un téléphone cellulaire à la subsistance communiquée avec d'autres. La plupart des résidants agissent dans régulier, par exemple, un employé de bureau, un professeur, un étudiant d'université. Et certains ont les mouvements aléatoires, par exemple, un vendeur. Ainsi, nous concevons le bagout de mobilité en tant que deux classes courantes et aléatoires dans notre simulation. Et tous nos résultats de simulation peuvent facilement mesurer à un plus grand secteur.

Un modèle de mobilité résout le problème d'imiter les mouvements réels des réseaux dans le vrai monde. Pour établir un tel modèle, la manière la plus franche est tracer les mouvements des stations dans un vrai réseau et puis de soustraire le modèle mobile. De cette façon, on doit observer pendant longtemps le mouvement d'un grand nombre de stations, pour obtenir l'information utile.

La simulation du PMA est basée sur des programmes de langue de C++. Dans la première phase de la simulation, les programmes imite le comportement d'un MU avec dans la gamme d'un petit réseau cellulaire, trace les mouvements du MU, apprend son modèle de mobilité, et construit Matrix prédictif. Dans la deuxième phase de la simulation, les programmes appliquent les différentes stratégies de gestion d'endroit, à savoir IS-41 et le PMA, et comparent le coût de gestion de chaque arrangement individuel.

Le coût de l'arrangement IS-41 est de deux aspects : Mise à jour d'endroit et recherche d'endroit. Les mises à jour d'endroit se produisent quand il y a une passation, ou un transfert basé par temps. La recherche d'endroit se produit quand il y a un appel d'arrivée, et le MU n'est pas trouvé dans la cellule enregistrée. Le coût de PMA se compose également de deux facteurs. Mais la mise à jour d'endroit est rarement produite dans l'arrangement de PMA, car l'algorithme indique ce qui est la prochaine cellule à aller. Cependant, si le MU tombe dans une cellule qui n'a aucune référence dans la prévision Matrix, alors l'arrangement IS-41 s'appelle temporairement jusqu'à ce que le disque soit trouvé après temps.

Sans appel d'arrivée, il n'y a aucun besoin de recherche d'endroit. Plus sont les appels d'arrivée plus là, plus la possibilité pour produire un plus grand coût de gestion est haute. Les appels d'arrivée dans la simulation est aléatoire distribués.

Dans la majeure partie de la recherche de théorie, le CMR (rapport d'Appeler-à-Mobilité) est employé pour étudier l'exécution de l'arrangement proposé sur le coût réduit. En fait, l'appel d'arrivée quotidien est directement proportionnel à l'appel au rapport mobile (CMR), c'est-à-dire, aux appels d'arrivée, le CMR plus haut. Et le nombre de l'appel d'arrivée est décidé largement par les activités personnelles d'un utilisateur. Il est peu raisonnable d'employer le paramètre, le nombre moyen d'appels en chaque cellule, pour comparer le coût. Tellement ici nous employons le nombre de l'appel d'arrivée c, en tant que notre paramètre de comparaison des coûts. La valeur du coût est par l'unité de coût.

7. RÉSULTATS D'EXPÉRIENCE ET ANALYSE DE LA PERFORMANCE

Nous avons étudié le comportement de mouvement de l'inter-cellule d'un utilisateur mobile à la vue de réseau, et temps-avons basé le comportement aléatoire et courant de mouvement à la vue de gestion d'endroit. En analysant le comportement d'un utilisateur mobile avec les deux cas du modèle de mobilité, ils ont la tendance presque semblable, c'est-à-dire, le coût relatif de PMA est moins qu'is-41. Et quand le c augmente, le coût le PMA est beaucoup moins que dans l'arrangement IS-41. IS-41 prend trop de coût, alors que PMA montrera un grand avantage actuellement.

Mais le coût relatif est inférieur dans le mouvement courant que dans les mouvements aléatoires parce que dans le cas du modèle aléatoire, le transfert se produisent plus fréquemment, et la probabilité à l'endroit de cellules de changement est très haute, et les disparus de recherche davantage, puis se produisent recherche d'endroit et augmentation de mise à jour. Ainsi nous pouvons conclure que le mouvement courant a l'exécution meilleure que le mouvement aléatoire. C'est la raison pour laquelle nous employant l'arrangement PMA pour tracer et comportement régulier de mouvement apprenant utilisateur mobile '. Et établissez alors le profil du MU pour l'exécution meilleure de la gestion d'endroit.

Avec ce modèle de simulation la gestion d'endroit est basée sur un profil d'utilisateur. Le mouvement classable a été modelé et formé au profil, qui capture la régularité dans le mouvement quotidien d'un utilisateur. Pour établir le profil d'utilisateur, nous avons proposé un algorithme d'étude bon pour tracer et enregistrer les mouvements d'histoire de l'utilisateur mobile l'étude du futur et l'utilisation, à savoir PMA. D'ailleurs, notre méthode efficacement a réduit de manière significative tout le coût de mise à jour et de recherche d'endroit. Il prouvé qu'avec cette méthode, la prévision raisonnablement précise peut être réalisée même lorsque le système n'a aucun n'importe quel appel d'arrivée. Comme modèle de simulation de l'exécution de système de PMA, un modèle annalistique a été présenté comme une comparaison possible à l'arrangement IS-41 standard, contribué pour la gestion prédictive de mobilité dans les réseaux sans fil de PSC. Les résultats de simulation prouvent que l'arrangement proposé PMA a l'exécution meilleure que l'arrangement IS-41. Et il montre également l'algorithme de PMA fonctionnant correctement et efficacement.

8. CONCLUSION ET TRAVAUX FUTURS

Avec la stratégie basée sur l'apprentissage de prévision, nous améliorons la performance de la gestion de localisation dans les réseaux mobiles. L'algorithme de PMA apprend l'histoire du mouvement de l'utilisateur pour obtenir les données de traitement et de la structure, finalement à l'aide du profil de l'utilisateur mobile on pourrait prédire la future position où l'utilisateur va se rendre.

L'algorithme démontre une performance prometteuse avec les résultats obtenus confirment l'efficacité de PMA en terme de réduire de manière significative les coûts des deux mises à jour de localisation et le coût de recherche des procédures comparé à IS-41.

L'exactitude du profil a l'affection sur l'exécution de notre arrangement, plus d'exactitude du profil, l'exécution meilleure. Mais la grande exactitude sera une différence avec certain surcoût. L'exactitude élevée doit aller avec de grands enregistrements, donc, il y a un besoin de nous de soulever la capacité de système. Avec les données montant, la période de la question à la base de données coûtera beaucoup plus, aussi bien que plus de calcul requis. Nous ne pouvons pas trouver ce qui est le meilleur critère de l'exactitude du profil. Pour la raison nous devrons faire un grand nombre d'expériences, étudiant et analysant pour trouver le point très exact de l'exactitude pour une bonne exécution sur la prévision d'endroit à l'avenir.

L'approche proposée exécute efficacement pour un utilisateur d'exister avec son enregistrement historique de mouvements. Il a besoin d'une observation à long terme afin d'obtenir des données de localisations pour former une liste de mouvements. Mais pour un nouvel utilisateur, nous ne prenons aucun record ou histoire de son comportement de mouvements au début. Cela prend du temps d'obtenir et apprendre les données de traitement pour établir son profil. Pour le travail futur de la recherche, nous allons trouver une méthode appropriée pour installer dynamiquement le profil d'utilisateur afin de satisfaire les besoins quand un nouvel utilisateur présente sans aucune donnée historique ni la connaissance de son comportement de mouvement.

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LIST OF ACRONYMS AND ABBREVIATIONS

3G	Third Generation Cellular System
BS	Base Station
CAMEL	Customized Applications for Mobile network Enhanced Logic
CDMA	Code Division Multiple Access
CMR	Call-to-Mobility Ration
FDMA	Frequency Division Multiple Access
FOMA	Freedom of Mobile Multimedia Access
GGSNs	Gateway GPRS Support Node
GSM	Global System of Mobile communication
GPRS	General Packet Radio Service
HLR	Home Location Register
IS-41	Interim Standard-41
LAs	Location Areas
LSTP	Local Signaling Transfer Point
MAP	Mobile Application Part
MH	Mobile Host
MS	Mobile Station
MSC	Mobile Switching Center
MU	Mobile User/Unit
NIC	Number of Incoming Call
PMA	Prediction Matrix Algorithm
PCS	Personal Communication System
RA	Routing Area

RSTP	Regional Signaling Transfer Point
SGSNs	Serving GPRS Support Nodes
TDMA	Time Division Multiple Access
UMH	User Movement History
UMTS	Universal Mobile Telephony System
URAs	UTRAN Registration Areas
UTRAN	UMTS Terrestrial Radio Access Network
VLR	Visited Location Register

Chapter 1
Introduction

In Third Generation (3G) Mobile Telecommunication Systems, global roaming becomes more practical with GSM, GPRS and UMTS co-existing to cover a global area. 3G have to provide the service of mobility to every subscriber in every part of the world. Today, only mobile network equipment is able to provide this service. Also, in order to stay in competition, a fixed or meshed network provider should offer mobility to his customers. The amount of signaling traffic due to mobility management will increase significantly, in mobile networks because of the rising volume of subscribers and the demand for higher transmission rates, and in fixed networks due to the deregulation of the market, because of the possibility for the subscriber to change the service provider by keeping his or her personal communication number. Both examples show the difference between possible user mobility processes: some users are highly mobile, whereas some are nearly static, but they should be able to change their location. To meet these highly variable demands, different mobility management algorithms have to be implemented depending on the user's mobility process. The changing demands on mobility management will alter methods of maintaining and processing the user's mobility data. A main objective of future research activities is to minimize signaling traffic. It is obvious that optimization techniques and efficient Location management algorithms are critical issues, concerning the overall 3Gs performance. The criterion to assess the optimum depends strongly on the kind of user behavior.

1.1 Definitions and Basic Concepts

3G is a generic name for a set of mobile technologies set to be launched by the end of 2001 which use a host of high-tech infrastructure networks, handsets, base stations, switches and other equipment to allow mobiles to offer high-speed Internet access, data, video and CD-quality music services.

One of the most important and challenging problems for 3G is mobility management. [1] Mobility management enables telecommunication networks to locate roaming terminals for call delivery and to maintain connections, as the terminal is moving into a new service area. Thus, mobility management supports mobile terminals, allowing users to roam while simultaneously offering them incoming calls and supporting calls in progress. A main aspect in mobility management is location management.

Location management

Location management is the procedure of keeping track of and locating Mobile Users (MU's) in mobile radio communication system so that calls arriving for them can be routed correctly to their current location. The main aim of the location management is to track the MU's using minimum overhead traffic. [4]

Location management plays the central role in providing ubiquitous communications services in the future wireless mobile networks. As a whole, the two fundamental procedures which comprise the basis of location management are location updates and pages. *Location updating* is initiated by the mobile station, and informs the network of the subscriber's current location area. *Search* is initiated by the network when an incoming call arrives. Paging messages are broadcast in one or more paging areas, contained within the current location area, and inform the target user of the incoming call.

1.2 Elements of the Problem

Unlike the resource management problems in cellular networks, the location management problem is user oriented by definition. Naturally, it would be wise to make use of personal mobility and calling profile of individual subscribers for optimization purposes. Both the update and paging techniques should be user specific to add the personal touch to the personal communication service. Knowledge representation and learning of user profile are thus two key factors.

The effectiveness of sequencing the paging process critically depends on early success of the deployed paging strategy. Large number of failed paging attempts would not only result in more call drops, but also cause overloading on paging channels. The essence of designing a good paging strategy is to enhance the predictability of a mobile's behavior making use of the user profile.

Since the sole purpose of the update mechanism is to aid the paging process, there is no reason to treat them as two independent components of location management cost. As opposed to deciding on a paging strategy first and then optimizing on the update strategy, one can come up with a collaborative pair of paging and update policies. In other words, the update mechanism needs to keep the system better informed about user's mobility, sending the maximum possible information in a compact form and avoiding redundancy as far as possible.

To make intelligent mobile-aware applications, it is important that a mobile terminal be more intelligent and can anticipate the change of the location of its user. New intelligent location tracking mechanisms can cope with this task. It's possible to develop an algorithm based on the paradigm of the prediction for learning. We may analyze information on the mobility of user, which can be used to help with the mobility management of user, with the knowledge of the traffic, the assignment of resources, the control of admission of calls and the control of flow.

The real power of an adaptive algorithm comes from its ability to learn. The object of our prediction scheme is to learn user mobility with optimal message exchange. Learning endows the management mechanism with a predictive power, which reduces average traffic cost. We survey the existing location management techniques, which have focused on the statistics like the mobility model, the user location tracking, trajectory prediction, channel holding time, cell boundary crossing rate, mean handover rate, and cell residence time.

1.3 Research Objectives

The principal objective of this research program aims at developing models and algorithms of mobility management based on the paradigm of the prediction for learning and planning, the dimensioning and the exploitation of the 3rd mobile network systems.

More specifically, this research has the following objectives:

1. Determine the gaps of the current methods and the proposals formulated by various researchers for mobility management in the 3rd mobile networks;
2. Specify the requirements of the 3rd mobile networks in terms of optimization of the cost of mobility;
3. Design models and algorithms for the mobility management (based on the paradigm of the learning for prediction), including the transfer between cells, the localization of the user and the quality of service, by taking of account the behavior (characteristics of mobility and traffic) of mobile users.
4. Implementation

1.4 Thesis Outline

The information and work presented in this thesis is organized as follows:

In Chapter 1, Introduction

In Chapter 2, recount some of the location management schemes followed by the detailed discussion of the location update and paging algorithms in 3G. Finally, a brief look at the novel location management scheme presented by us, namely, Prediction Matrix Algorithm (PMA).

In chapter 3, we give a detailed description of the learning-based location prediction scheme, as well as a simulation model is present.

In chapter 4, we give the analysis of our system. The goal is to obtain the evaluation of the performance. And we compare our PMA location management algorithms proposed here or with some previous methods proposed before. Right through these discussions, we could see the property of our scheme.

In chapter 5, summary, conclusion and suggestions for future work are presented.

Chapter 2
State of the Art

This chapter begins with an introduction to Third Generate (3G) Mobile Telecommunication Systems. And then followed by detailed discuss to the different types of location tracking schemes presented in the literature for the purpose of location management.

2.1 Introduction to 3G

Future telecommunication systems have to provide the service of mobility to every subscriber in every part of the world. In 3G, only mobile network equipment is able to provide this service. Also, in order to stay in competition, a fixed or meshed network provider should offer mobility to his customers. The amount of signaling traffic due to mobility management will increase significantly, in mobile networks because of the rising volume of subscribers and the demand for higher transmission rates, and in fixed networks due to the deregulation of the market, because of the possibility for the subscriber to change the service provider by keeping his or her personal communication number. Both examples show the difference between possible user mobility processes: some users are highly mobile, whereas some are nearly static, but they should be able to change their location. To meet these highly variable demands, different mobility management algorithms have to be implemented depending on the user's mobility process. The changing demands on mobility management will alter methods of maintaining and processing the user's mobility data. A main objective of future research activities is to minimize signaling traffic. Mobility management methods need to be optimized. The criterion to assess the optimum depends strongly on the kind of user behavior.

Ultimately, 3G is expected to include capabilities and features such as:

- Enhanced multimedia (voice, data, video, and remote control)
- Usability on all popular modes (cellular telephone, e-mail, paging, fax, videoconferencing, and Web browsing)
- Broad bandwidth and high speed (upwards of 2 Mbps)
- Routing flexibility (repeater, satellite, LAN)
- Operation at approximately 2 GHz transmit and receive frequencies
- Roaming capability throughout Europe, Japan, and North America

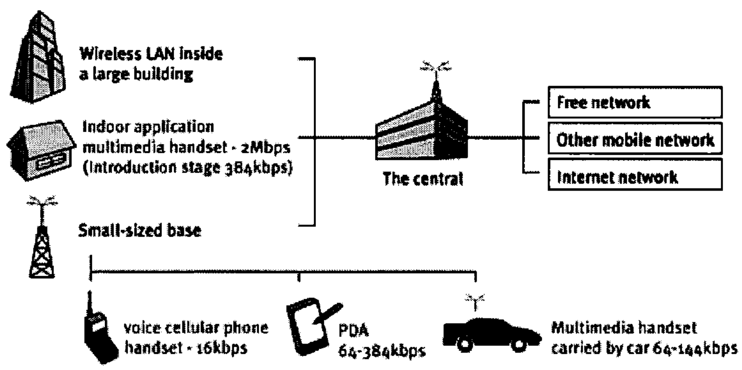

Figure 2-1: 3G Developments

2.1.1 History of Wireless Telecommunication System

Wireless systems have been developed in an evolutionary way generation by generation over the last twenty years or so. 1G systems are of diminishing importance. The dominant generations today are 2G and 2.5G with 3G coming into use and are represented in Europe by GSM, GPRS and UMTS, respectively. [25]

2G (GSM)

GSM for example is a 2G technology. It uses TDMA technology, proving data speeds of 9.6kbps/14.4kbps. Mobile terminals and users authenticate and identify themselves by reporting their locations to their Home Location Registers (HLRs) through the MAP (Mobile Application Part) messages. The Visited Location Registers (VLRs) store caches of necessary user information locally. A mobile terminal updates its location when crossing location areas (LAs) which are sets of cells.

2.5G (GPRS)

The packet radio upgrade to GSM, called GPRS, can have speeds of up to 114kbps. GPRS an interim technology towards 3G, and hence is known as 2.5G. Mobile terminals report their locations to their HLRs through SGSNs (Serving GPRS Support Nodes). The location area unit that GPRS uses is Routing Area (RA), which is typically a subset of one, and only one, GSM LA. This smaller granularity allows for signaling and paging over smaller areas, and thereby achieves a better optimization of radio resources. GPRS co-operates with the GSM LA-based location management, resulting in a more efficient paging mechanism for mobile terminals that use GSM and GPRS simultaneously. Although IP networks were introduced between SGSNs and GGSNs (Gateway GPRS Support Node), GPRS is only a step preparing for other than using IP mobility by tunneling IP, and in principle, the mobility management of 2G and 2.5G are both Link-Layer based and for terminal mobility only.

3G (UMTS)

In UMTS, mobile terminals report their locations to their HLRs through combined GSNs and GGSNs. In a later phase, Mobile IP (RFC 2002) would be introduced for IP mobility. By then, SGSNs and GGSNs would have been integrated and the integrated node would act as the home agent of the mobile terminal. In contrast to the monopoly role in GPRS, UMTS SGSN shares mobility management with the UMTS Terrestrial Radio Access Network (UTRAN). For further thinning location management requirements, RAs are in turn partitioned into URAs (UTRAN Registration Areas) to better serve pico-cells. The IN (Intelligence Network) concept was evolved to facilitate service mobility. In UMTS, it is called Customized Applications for Mobile network Enhanced Logic (CAMEL).

CDMA

The new 3G services are almost all flavours of technologies based on the generic name, CDMA (Code Division Multiple Access). CDMA is a digital wireless technology that allows multiple users to share radio frequencies at the same time without interfering with each other. A telephone or data call is assigned a unique code that distinguishes it from others and since the signals hop among different frequencies.

Current 2G services using the original CDMA "IS-95" technology is know as cdmaOne. 3G services will use new high-speed versions of CDMA called W-CDMA, or its competing technology, cdma2000.

W-CDMA is the competitor to cdma2000 and one of two 3G standards that makes use of a wider spectrum than CDMA and therefore can transmit and receive information for faster and more efficiently. Co-developed by NTT DoCoMo, it is being backed by most European mobile operators and is expected to compete with cdma2000 to be the de facto 3G standard

- UMTS (W-CDMA)

In Europe, 3G W-CDMA networks are known as UMTS (Universal Mobile Telephony System) another name for w-CDMA/3G services. UMTS represents an evolution in terms of services and data speeds from today's "second generation" mobile networks. As a key member of the "global family" of third generation (3G) mobile technologies identified by the ITU, UMTS is the natural evolutionary choice for operators of GSM networks, currently representing a customer base of more than 850 million end users in

195 countries and representing over 70% of today's digital wireless market [30].

- FOMA (W-CDMA)

Japanese giant NTT DoCoMo Inc brand name for 3G services is FOMA (Freedom of Mobile Multimedia Access). Based on the W-CDMA format, FOMA services for a limited number of users is to begin at the end of May, with full commercial services due in October 2001.

CDMA2000, the other 3G standard. It is the upgrade to cdmaOne. It can use of a wider spectrum than CDMA and therefore can transmit and receive information faster and more efficiently, making fast Internet data, video, and CD-quality music transmission possible. There are however new cdma2000 variants called cdma2000 1X, 1X-EV-DV, 1X EV-DO, and cdma2000 3X. They deliver 3G services while occupying a very small amount of current spectrum (1.25 MHz per carrier) as opposed to UMTS which requires completely NEW spectrum (hence the auctions).

2.1.2 Mobility Management in Wireless Telecommunication System

Mobility Management

Mobility management contains two components: location management and handoff management.

Location Management

Future mobile networks will have to support large population of mobile users and have to provide efficient and low-cost services under diversified characteristics of network architecture, services, and user types, i.e. different cell sizes, multimedia services, different mobility users, etc. One of the most important issues in the mobile networks is the location management.

Location updating and page will incur signaling traffic in the wireless networks. The more frequent the location updates, the less paging in locating a mobile user, thus there is a tradeoff in terms of signaling cost. [6] The total cost for location management is the sum of location update cost and paging cost. Paging cost is the number of calls arrived and the number of cells paged. Update cost is the number of times mobile updates, so the more the paging the less the update. Some optimal algorithm is required, that is, call routed with allowable time constraint and less information exchange.

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Owing to the resource consumption of current location strategies, and the increased needs in wireless services, it is easy to predict that the radio channel bottleneck will rapidly restrain the increase of mobile customers population. Some new location management procedures must be provided effectively and efficiently for future high-density wireless systems.

Handoff management

Usually in wireless cellular communication system, continuous service is achieved by supporting handoff (or handover) from one cell to another. Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel. [21]

Handoff is divided into two broad categories— hard handoff and soft handoffs. They are also characterized by "break before make" and "make before break." In hard handoffs, current resources are released before new resources are used; in soft handoffs, both existing and new resources are used during the handoff process. Poorly designed handoff schemes tend to generate very heavy signaling traffic and, thereby, a dramatic decrease in quality of service (QoS). The reason why handoffs are critical in cellular communication systems is that neighboring cells are always using a disjoint subset of frequency bands, so negotiations must take place between the mobile station (MS), the current serving base station (BS), and the next potential BS. Other related issues, such as decision making and priority strategies during overloading, might influence the overall performance.[3]

A hard handoff is essentially a "break before make" connection. Under the control of the MSC, the BS hands off the MS's call to another cell and then drops the call. In a hard handoff, the link to the prior BS is terminated before or as the user is transferred to the new cell's BS; the MS is linked to no more than one BS at any given time. Hard handoff is primarily used in FDMA (frequency division multiple access) and TDMA (time division multiple access), where different frequency ranges are used in adjacent channels in order to minimize channel interference. So when the MS moves from one BS to another BS, it becomes impossible for it to communicate with both BSs (since different frequencies are used). Figure 2-2 illustrates hard handoff between the MS and the BSs.

Usually, the hard handoff can be further divided into two different types – intracell and intercell handoffs.

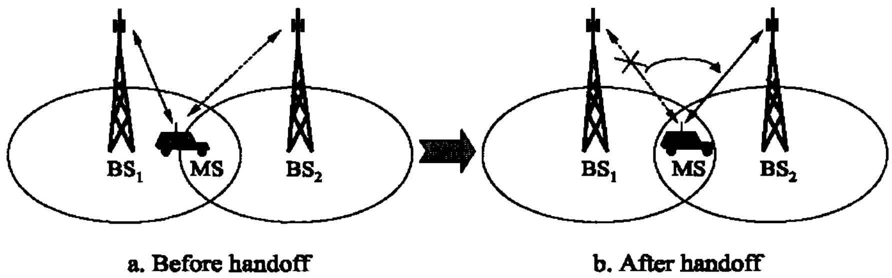


Figure 2-2: Hard handoff between the MS and the BSs

- Inter-cell handoff

  Intercell handoff occurs when the user moves into an adjacent cell and all of the terminal's connections must be transferred to a new BS.

- Intra-cell handoff

  Intracell handoff occurs when the user moves within a service area (or cell) and experiences signal strength deterioration below a certain threshold that results in the transfer of the user's calls to new radio channels of appropriate strength at the same base station (BS).

Handoff (or handover) processes are essentially based on radio aspects, and the main difficulties in improving handover procedures' performance come from unpredictable and highly fluctuating radio channel behavior [22]. Handoff management enables the network to maintain a user's connection as the mobile terminal continues to move and change its access point to the network.

2.2 Location Management Schemes in 3G

Compared to second-generation systems and apart from the increased traffic demands, the employment of location management and handover procedures in a micro- cellular environment, in conjunction with the huge number of MUs, will generate a considerable "mobility-related signaling" load. The increase of mobility-related signaling - apart from the radio link- will have a major impact on the number of database transactions, thus causing the database to be a possible bottleneck at the fixed network side. Consequently, given the scarcity of radio resources, methods for signaling load reduction are emerging for 3Gs. It is obvious that optimization techniques and efficient location management algorithms are critical issues, concerning overall 3Gs performance.

The following are some methods of location management for third generation communication system, which are divided into two main groups: static or dynamic.

- Static, based on algorithms and network architecture, mainly on the processing capabilities of the system, update triggered because of network topology.
- Dynamic, gathers the methods based on movement processes which require the collection of statistics on user's mobility behavior, for instance, it emphasizes the information capabilities of the network, update depends on user's call and mobility patterns.

2.2.1 Static Algorithms

For the static location update, the classical method that is used widely in current networks uses fixed and network wide location areas. [5] All subscribers have the same cell borders to send location updating messages. That leads to a signaling traffic burst on the signaling channels of cells that are on the location area border, whereas other cells have idle control channels. The paging area is the same as the location area; for that reason the location of the subscriber is well known and he is found within one paging attempt, which minimizes the paging delay. This knowledge is paid for at the price of a high volume of signaling.

- Partitioning

Location Areas (LA) is a popular location management scheme in cellular networks [4]. In the location areas scheme, the service coverage area is partitioned into LAs. Each location area consists of several contiguous cells. A mobile terminal will update its location whenever it moves into a cell that belongs to a new location area. On a call arrival for a particular mobile terminal, the cellular system will page all cells within the location area reported by the mobile terminal at its last update. LA size is important for the network performance. [10]

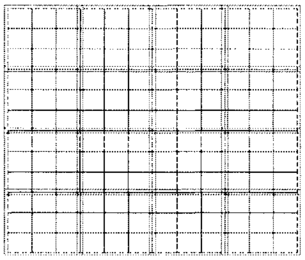


Figure 2-3: Partitioning

A second proposal is the optimal search method, which uses paging areas (PA) that do not correspond to the location areas; however, the concept of fixed location areas is still used. The paging operations are reduced by using the theory of optimal search and learning from historical search results [17]. Paging strategies for highly mobile users are discussed in [2]. These methods lead to better performance with respect to the signaling cost for paging operations. The maximum paging delay has to be fixed using these methods to guarantee the quality of service. For that reason it is necessary to define an upper bound on the number of paging attempts. Location updating messages are not saved with the optimal search methods. When using the adaptive methods, saving depends on the mobility characteristics of the user.

- Reporting cell

The method which uses reporting cells and nonreporting cells is proposed in [25]. Only the reporting cells inform the network of the location change. The number of cells in which the subscriber is located is always known. The simulation shows better performance than using the strategies *always update*, that means sending a location update upon every cell border crossing, and *always search*, which means paging in the whole service area each time an incoming call request is busy. These results are to be expected.

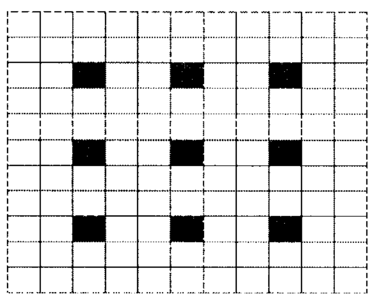


Figure 2-4: Reporting cell

Static update strategies can be inefficient because they are common to all users, and cells in the border of location areas tend to have higher location update traffic.

While dynamic location update schemes are required in which the updates are mostly based on individual user mobility patterns.

2.2.2 Dynamic Algorithms

- Optimum LAs

  Analytic approaches are based on assumptions of homogeneous cell shape, LA structure, and user's movements. Common approaches for modeling human movements are mentioned in [14], including:

- The Markovian model, also known as the random-walk mode, is a model, which describes individual movement behavior.
- The fluid model considers traffic flow as the flow of a fluid, modeling macroscopic movement behavior.

• Multilevel LAs

The size of LAs is optimized according to mean parameter values, which in practical situations vary over a wide range during the day and from one user to another. Based on this, it's proposed to manage user location by defining multilevel LAs in a hierarchical cellular structure. [24]. At each level the LA size is different, and a cell belongs to different LAs of different sizes. According to past and present MS mobility behavior, the scheme dynamically changes the hierarchical level of the LA to which the MS registers. Update saving s can thus be obtained.

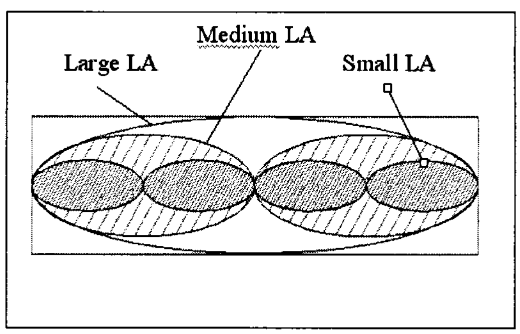


Figure 2-5: Multilevel LAs

• Movement-based

In this scheme, the mobile provides an update when it crosses exactly k cell boundaries.[19] Mobile terminal counts number of boundary crossings and location update is done when threshold exceeded (e.g. M = 6). It allows dynamic selection based on per-user basis. For the implementation, mobile terminal (MT) only needs a counter, which will be reset when threshold hit. And then *cell identification code* (CIC) can be used. CIC is not necessarily unique but for orientation to other cells. Each cell periodically broadcasts its ID code. It's applicable for mesh and hexagonal cell configurations[7]. Assumed, general cell residence time distribution and symmetric random walk. Shortest-distance-first order paging scheme used here.

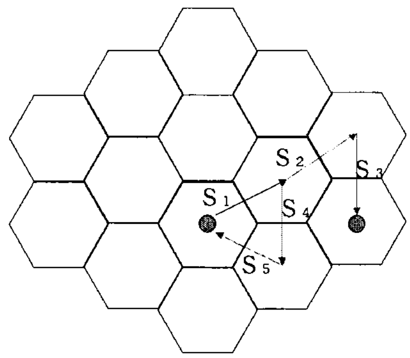


Figure 2-6: Movement-based Location Tracking

- Time-based

In this scheme, the mobile provides a periodic update exactly once every t time units. [19] Between times, there is no record or process location information. The timer can be hardware or software. There is a variation called adaptive threshold scheme, in this scheme, time t is not a constant but varies with signaling load. Here, we need introduce a parameter called the CMR: call-to-mobility ratio (Call frequency/ mobility degree), Which has an effect on the time t,

CMR increased ➔ t decreased
CMR decreased ➔ t increased

- Distance-based

In this scheme, the mobile provides an update when its location is more than k cells away in distance from the location of the last update. [19] The distance measured in cells and update is transmitted when some threshold exceeded. The optimal distance threshold is determined by using dynamic programming. Mobile terminal needs some knowledge of network topology. It needs a set of cell IDs within distance threshold after each update. This scheme has been studied extensively, for it has the following advantage:

- Flexible
- Load-balanced
- Low location tracking cost
- Simple implementation and low computational cost on mobile terminals
- Lower location management cost than time-based and movement-based.

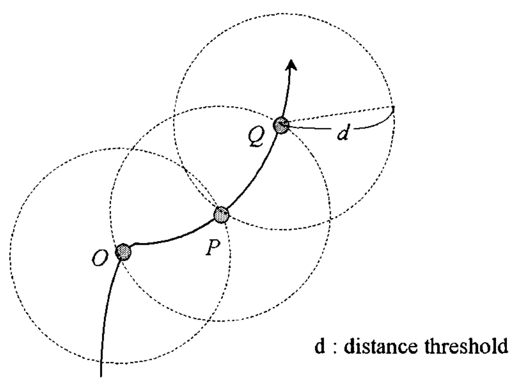


Figure 2-7: Distance-Based Location Tracking

- State-Based

  Mobile terminal performs location update based on its state, using current location and time elapsed since last update. The state information could be time elapsed, cell crossings, cell distance, or some other criteria. Different state information should be maintained in order to analysis different location update schemes. The scheme is modeled on user's movement using time-varying Gaussian process.[19] It uses greedy method for location update and paging. State-based location update has 10% improvement over timer-based location update.

2.2.3 Intelligent Methods

Location management is a very important and complex problem in today's mobile computing environments. There is a need to develop algorithms that could capture this complexity yet can be easily implemented and used to solve a wide range of location management scenarios. Intelligent location update and paging methods have been used to solve a wide range of complex problems in recent times. These algorithms have hugely contributed to location management schemes. Most of the existing works on these algorithms based on user's profile by learning processes, update depends on user's call and mobility pattern.

- Prediction Location

  Time and state dependence can be integrated, by using neural networks to predict the location. As mentioned in the above paragraphs, the historical movement pattern is recorded. A neural network is trained with these data in parallel or after an observation period. To find the possible location of a subscriber, the last known locations and the actual time are presented to the neural network, which provides an output to predict the next location [23]. This method makes greater use of computational power but is able to save more signaling messages than the other methods for specific user behavior. [5]

- LeZi Update

  The technique evolves out of the concepts of lossless compression originally proposed by Ziv and Lempel. The responsibility of generating the movement history "v1v2v3…" still lies with the primary update scheme as before.[20] LeZi update really makes a paradigm shift from the existing zone-based to a new path-based update messaging, where movement history, not current location, is sent in update message in an encoded form. The history has a list of zone (LA or cell) ID's the mobile terminal crossed. Network database has history in compact form of trie or digital search tree, it can be a part of the user's profile, on call arrival, and selective paging is based on the trie. The compressibility of the variable-to-fixed length encoding of the acclaimed Lempel Ziv family of algorithms reduces the update cost, whereas their built-in predictive power can be effectively used to reduce paging cost.

By building and maintaining a dictionary of individual user's path updates (as opposed to the widely used location updates), the proposed adaptive on-line algorithm can learn subscribers' profiles. The principle of using compression techniques in mobility prediction may have a bigger potential than just efficient location management. By maintaining global dictionaries along with individual user profile decoded from updates, it may be possible to predict group behavior. In wireless data networks, this can lead to a more efficient bandwidth management and QoS provisioning based on reservation.

- Profile-based

  A profile-based strategy (also known as the alternative location strategy) is proposed to reduce the signaling traffic on the radio link by increasing the intelligence within the fixed network. [8] The system maintains a sequential list of the most likely places where each user is located. The list is ranked from the most to the least likely place where a user is found. It can reduce update cost via user's mobility pattern. Its operation is based on the observation that most users follow regimented daily schedules that can be exploited to estimate their current location.

  With profile-based strategy, network maintains a profile for each user with list of LAs, and then a sequential list of LAs is sorted from most to least likely probability. [12] When a call arrives for a user, it is paged sequentially, in the order indicated by the list. If a user moves between location areas in the list, a location update is not required.

As an example, a set of LA's of {a,b,c,d,e,f,g}, a time period (t1,t2), the sequential list for the mobile terminal is {b, a, e, f}, then there isn't any update required if mobile terminal stays in list. Upon a call arrival, the network will page location area b first, followed by location a, an so on, until the mobile terminal is found or the list exhausted. For implementation, each mobile terminal must maintain a valid sequential list corresponding to a particular time interval. This list is updated periodically.

- AS strategy

  An alternative strategy (AS) for reducing location update (registration) signaling load by prediction users movement patterns. It is based on user movement habits, which was proposed to improve the classical strategy used in the global system for mobile communications. In this strategy, the system handles a profile for each user, where each users most probable mobility pattern is recorded [11]. The structure and contents of this profile for an MH are as follows:
  over a period of time[ti, tj], it crosses k LAs.

The profile consists of two elements: a_f, p_f) with 1<= f <= k, where k is the number of LAs. Where a_f is the identifier of the *f*th LA that an can be located in and p_f is the residence probability that the MH is located in a_f, which $p_1 >= p_2 >= \dots p_k$

The profile of each user is stored in HLR(Home Location Register. When the subscriber moves away from the recorded zone $\{a_1, \dots a_k\}$ during the corresponding period $[t_i, t_j]$, the terminal processes a voluntary registration by pointing out its presence to the nearest Base Station(BS). This procedure enables the system to track the users by involving low location updates rate and by obtaining high location knowledge accuracy. To allow this procedure, each user must have the copy of the profile stored at the network side. This requirement is crucial for normal processing of AS. The copy of the profile is updated when a change occurs at the network side.

This AS scheme main advantage is to save location updates by storing user's mobility information (in profile form). Its drawbacks are the possibly increased paging delays (when the system must page a user in different locations in a sequential manner), the increased memory requirements, and finally, the profile updating costs for users who do not have long-term periodic mobility patterns.

In fact, the system should record two kinds of information: long-term and short-term, concerning only the long or very long periods of time and reflecting the recent user's behavior, respectively.

AS with Short-Term Events

The AS is suitable for long-term events and fixed movement tracks. Location tracking (paging) costs more when the Mobile Host (MH) changes movement habits or encounters short-term events, so the strategy[12] takes user recent movement information (called the paging information record) into account to determine which location area to page first.

Based on the AS strategy, it adds a new data item and store it in the HLR. The data item is called "paging information records", the paging information record has three fields, as follows:

LAI: the location area identifier identifies the LA in which an MH communicated with the location management system during the most recent time period. Communication events including the MH entering a new LA that is not in the LA list, the MH having a call to deliver, and a call for the MH, must be recorded.

Time: This is the start time (last connection time) when an MH had a connection with the location management system. This is an important factor in deciding which LH to page first for call delivery.

Tag: This is a mark (1; successful; 0: unsuccessful) to let us know if an lA has ever been successfully paged during the observation period before an MH updates the profile in the system. It is a factor to decide an offset(W). if there are I paging information records with 1 in the Tag files, the offset(W) is defined as:

$$W = I * w$$

Where w is a weighting parameter. W is an offset that the location management system should add to the pfs of all LAs sequence in the LA list. The purpose of W is to express the most recent history of th MH.

The AS is suitable for situations of high mobility rate and small LA size because it significantly reduces the location update costs compared to the CS, the approach further reduces location tracking costs in comparison with the AS, without increasing location update costs. The overhead of the approach is the additional storage space (for sorting MH profiles and paging information records) and additional processing time required.

Multiple Step Paging

The key idea here [14] is the application of a multiple step paging strategy which operates as follows: At the instance of a call terminating to a mobile user which roams within a certain location area, paging is initially performed in a portion of the location area (this location area portion constitutes the paging area) that the so-called *"paging related information"* indicates. On no paging response, the mobile user is paged in the complementary portion of the location area -this phase can be completed in more than one (paging) step. Various *"paging related information"* elements (e.g., recent interaction information, high mobility flag, etc.) can be used and several "intelligent" paging strategies can be defined.

There are two phases identified: "*Selection phase*" and "*Execution phase*". During *Selection* phase the network determines the "appropriate" paging strategy to be applied. I.e., either a single step paging strategy ("GSM-like" approach) or a multiple step one ("intelligent" paging) is selected. During *Execution* phase the actual execution of either the Single or the Multiple Step Paging Strategy is performed. With *Single Step Paging Strategy,* paging is performed within the whole LA. With *Multiple Step Paging Strategy,* the PA for the first paging step is determined based on the "paging related information". Then, paging is performed within the selected PA. If paging fails another step is (or multiple steps are) required.

This method achieves a significant reduction of the paging signaling load compared to the technique applied in GSM. This allows for the definition of large scale LAs and therefore may lead to the minimization of the location updating signaling load (e.g. a single LA may cover a whole city area). The penalty paid is:
additional storage space is required in the network database (the *"MU-related"* paging information) and some additional functionality is needed to process the "paging related information". However, neither the storage or the processing requirements can be considered significant as far as the applicability of the "intelligent" paging strategies is concerned.

Dynamic Individualized Algorithm
In [26], a location management algorithm is proposed which uses the mobility history of individual subscribers to dynamically create individualized location areas, based on previous movements from cell to cell. The average duration spent in each visited cell is also maintained and is used to define paging which are most likely to contain the

subscriber. An activity-based mobility model was developed to test the proposed algorithm.

The proposed location management algorithm attempts to utilize the mobility history, or user profile, of the subscriber to dynamically create location areas for individual subscribers and to determine the most probable paging areas. The user profile contains transitions from cell to cell, and average visit duration for visited cells and maintained in real-time. It consists of two procedures:

Location update procedure

- Neighboring cells with transition rates greater than or equal to the average are added to dynamic location area in order
- Fixed location area overlays used when new cell is not in user profile
- Process repeated until DLA fills up, or no more linked cells

Paging procedure

- During a location update, mobile station transmits average visit duration for each cell in DLA
- Cells with visit duration greater than or equal to overall average of visit durations form first paging area
- If unsuccessful, all cells in DLA are paged

The dynamic algorithm significantly outperformed the fixed algorithms in terms of total location management cost, at a small cost of additional logic and memory in the mobile station and network. Overall, the dynamic algorithm incurred significantly lower location management costs, in terms of signaling messages generated, for all parameters examined.

- Adaptive Fuzzy Inference Approach

Predicting the probabilities that a mobile user will be active in other cells at future moments poses a significant technical challenge to network resource management in multimedia wireless communications. The probability information can be used to assist base stations to maintain a balance between guaranteeing quality of service to mobile users and achieving maximum resource utilization.

A novel adaptive fuzzy logic inference system to estimate and predict the probability information for direct sequence code division multiple access (DS/CDMA) wireless communications networks is proposed in [27]. The estimation is based on measured pilot signal strengths at the mobile user from a number of nearby base stations, and the prediction is obtained using the recursive least square (RLS) algorithm.

The adaptive fuzzy inference system is developed to predict the probabilities that a mobile user will be active in the nearby cells at future moments using the real-time measurement data of the pilot signal powers received at the mobile user from the BSs. The advantages of the adaptive fuzzy inference system lie in:

- Its simplicity – it is a one-pass build-up procedure that does not require time-consuming on-line training
- its usefulness – the probabilities are critical for balancing efficient utilization of the network resources and satisfying the QoS requirements of mobile users.
- its low cost – the predicted probabilities are obtained based on the existing signaling in CDMA networks for handoff, without requiring extra signaling over wireless channels.
- User Mobility Pattern Based on User Mobility History

In [28], a new location management scheme, namely the user mobility pattern (UMP) scheme, where MTs maintain their history data in a data structure called user mobility history (UMH).

Mobile subscribers usually follow a limited number of mobility patterns in their daily lives. In the UMP scheme, an MT collects the data related to these patterns in UMH, and predicts the UMP based on the collected data. During location updates, the expected UMP is registered to the network.

A UMP is a list of cells expected to be visited starting from a given time according to the mobility history of a mobile, and is made up of a number of nodes that have two fields, namely, cell identification (cell id) and expected cell entry time. A cell id and expected cell entry time pair identifies a node, which is unique in a UMP.

UMPs are derived from UMH which is a data structure where the mobility history of an MT is stored. Each MT manages its own UMH which is composed of a limited number of records with the following fields:

- flag
- UMP identification (UMP id)
- cell id

During location updates, an MT derives a UMP from its UMH, and registers it to the network. UMPs consist of a number of nodes made up of a cell id and an expected cell entry time. Unless the MT detects that it moves out of the registered UMP, it does not perform another location update. Upon a call arrival for the MT, the cells in its last registered UMP are paged sequentially according to the expected cell entry times. If a delay bound id reached before receiving a reply from the MT, all of the unpaged cells are polled simultaneously.

The scheme creates less location update traffic than the other techniques, such as time-based and movement-based location update techniques when reasonable time intervals and movement thresholds are used. It always outperforms the other techniques in paging performance.

2.3 Learning-based Location Prediction Scheme

These intelligent location management methods which are profile-based focus on the user profile or user previous movement behavior have been suggested in the above methods as a way to individualize location areas, thus with a user profile, reduce both the radio bandwidth and fixed network signaling load for a modest increase in call setup delay and therefore, an attractive candidate for future wireless systems. However, the detailed contents of the user profiles, as well as procedures for their creation and maintenance, are not well-defined.

A learning-based location management scheme based on learning for locating a mobile User (MU), which depends on its movement pattern, can be proposed later. The scheme is also a profile-based location update strategy, but it focuses on producing and maintaining the list of the user profile, as well as improving its performance. And then we may build a model in city area environment referring to the city area model [1] for mobile movement prediction can be designed to predict the future movement of a mobile user.

In our approach, using the prediction matrix methods, the system will learn the user's daily behavior by observing and recoding the movements of the user. With the date sets got from the learning process, we will train the network to get a most probability for the next location area in a list. And then we can induce a sequential list of the most likely places where each user is located.

Chapter 3
Learning-Based Approach to Location Prediction

The proposed method, namely Prediction Matrix Algorithm (PMA), is based on the probability theory and intelligent learning. The main motivation of the use of PMA is their ability to learn the relationships between the mobile user movement behaviour and user profile and then predict the future locations.

The scheme for mobile movement prediction is based on the history of the movement of the mobile user (MU), which has been recorded for certain time duration, called User Movement History (UMH). This method is implemented with a learning graph and a prediction matrix. In this method, we feed the training data from UMH to a learning tree, in which the nodes present the cells to which MU will go to at different time, and the lines represent a path that MU go during a day on observation. The tree is a weighted graph, and the weight represents the probability to next node. After bread-first searching in the tree we obtain the best gain, it is the most possibility path for the MU in question. And then the result will be used for generating the Prediction Matrix. The elements in the PMA are presented as a probability at some time for a MU from a cell to next cell. Finally after some Matrix operation, we will obtain the right state of the MU, that is the user profile.

3.1 Architecture

Mobility is the primary advantage offered by Personal Communication Systems (PCS). Location management is one of the most important issues of mobility management. The location management techniques consists of partitioning the coverage into many location areas(LAs) which are set of cells. Mobile Users (MUs) within a cell communicate with a cell base station(BS) through wireless links. BSs, in turn, are connected to the wireline network through a mobile switching centre (MSC) which serves one LA. Each MSC is identified by a unique address. This address is stored in the memory of the MUs that are roaming in the MSC's LA and is broadcast by the BSs of the cells within that particular LA. The MU compares the broadcasted address with the address stored in its memory. When these two addresses are different, the MU recognizes that it has move to a new LA and sends a registration message to the MSC of the new LA. The MSC then forwards this message to the network database.

Two major standards are used for location management, namely IS-41 and GSM. We consider only the IS-41 standard. This standard uses a two-level database architecture consisting of a Home Location Register (HLR) and Visitor Location Resisters (VLRs). Each network comprises one HLR and many HLRs. The VLR is a centralize database containing the profiles of it assigned subscribers. Most of the current PCS manufacturers implement a combined MSC and VLR with one VLR per MSC. A VLR stores the profiles of the MUs that are currently residing in its associated LA. Figure 3-1 shows the PCS architecture and signalling network.

3.2 Proposed Method

When the mobile terminal moves to neighboring location area, the location update scheme that proposed in the IS-41 standard increases location update cost. Also, when the mobile terminal calls the mobile terminal in the neighboring location area, the location query scheme that proposed in the IS-41 standard increases location query cost.

Since mobile terminals communicate with neighboring users frequently, call patterns between callers and callees have call locality. Also, since probability that mobile terminals move to neighboring location areas is higher, user mobility patterns between old location and new location area have mobility locality. Considering call locality and mobility locality, we build a user profile by learning managed by the HLR and the location information of the mobile terminals is registered at the home area. So the proposed location management scheme can reduce location update and query cost.

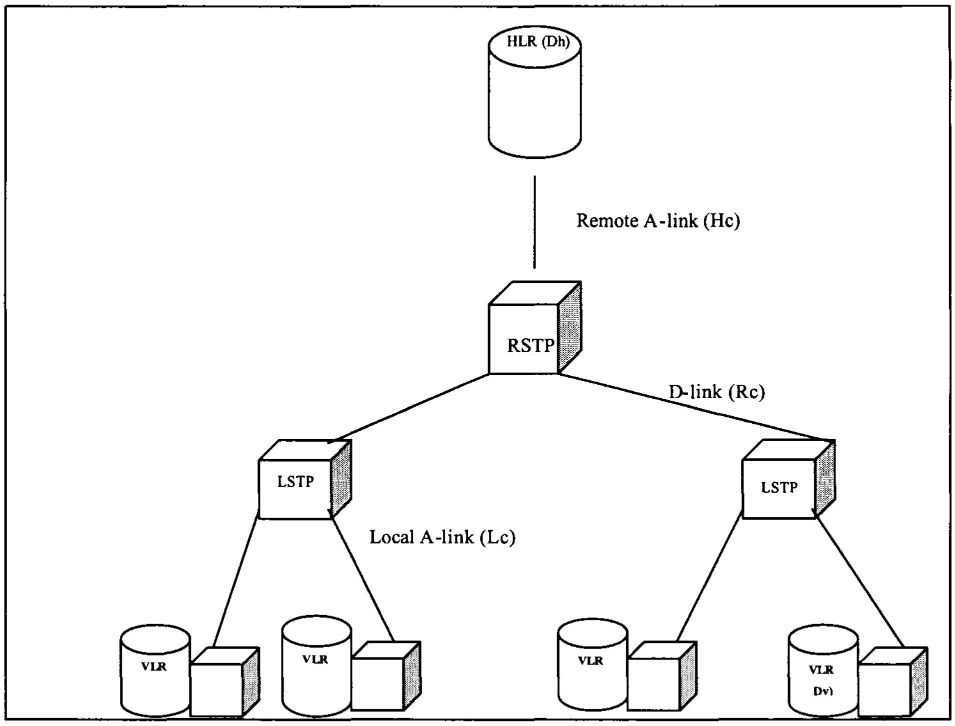


Figure 3-1: Network Architecture

In fact, the behavior of a person is quite regular, as we know from road traffic surveys and traffic flow theory [9]. Using methods from road traffic theory, this regularity behavior can be modeled with activities as "home", "work", spare time activities such as "sport" and resulting paths (e.g. ways) between them These surveys have shown that the geographical behavior is quite stable in the sense of repeated activities at the same place. But the rhythm in the sense of repeating activities at the same time every n days is not so stable. For a typical person, 2-4 activities cover 75% and 8 activities cover 85% of all movements observed over four weeks. [16]

With respect this regularity, we developed an efficient easy and powerful method, which allows a future more prediction of user's movement path on the user profiles generated by the above method. All geographical points (e.g. home and work) along a route will be will be stored as a path in the user profile.

3.2.1 User Movements History (UMH)

In Chapter 2, we have discussed about how user profile could reduce location management cost. This section we will present a practical method to learn, extract a user's history record in order to build a user profile. To make the description more intuitive, we will demonstrate the building of a user movement history with a town example, which has only nine cells.

In our example, there is a small town called Ubiq, which is covered by 9 cells. See Figure 3-2, the map of the town.

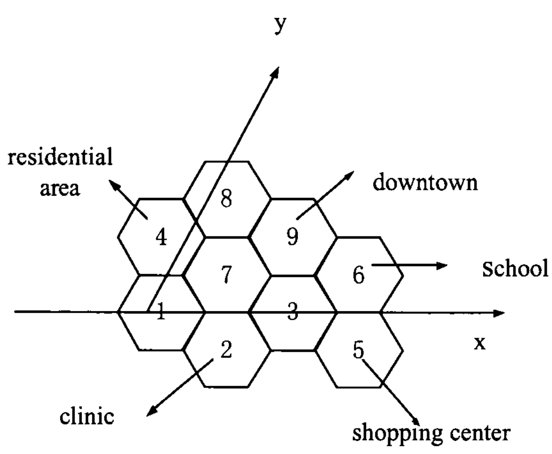


Figure 3-2: Ubiq town map

We assume, the villagers of Ubiq town are all living in the area of radio coverage. There are firms, services, schools, shopping centers, farms, plants, banks, and so on. Long story short, people in the town can find every thing they need, hence they only live in the town and never leave. Everybody in the town has a cellular phone to keep communicated with others.

To identify the 9 cells, we assign each cell a sequence number, namely, from 1 to 9. With the establishment of the cell coordinate, we can say, for example, Mr. Smith is now in Cell #7, as shown in Figure 3-2.

In order to learn a user's profile, first we need to trace his movement. Next, as example, we trace the movement of a fictions Ubig town citizen, Mr. John Smith, in a day.

In the morning, John gets up at 8:00 am and enjoys his breakfast at home. He went to office at 9:00 am and worked there until 12:30 pm. Then he had lunch at fast food restaurant from 12:30pm to 13:30pm. After that he had an appointment with his dentist at 14:00pm. The appointment took John 2 hours and he did not go back office. After he left the dentist's clinic. John went to a coffee bar at 16:00pm and there he met his girl friend Jennifer. They went to a restaurant for dinner at 9:00pm and had a very good time there. They went to cinema at cinema at 20:00pm. 22:00pm, John sent Jennifer home and went home.

In the evening, we do not care John is at where, doing what, and with whom. We just interested in when he is at which cell. Then John's movement of that day is interpreted as the following figure:

Time duration	Cell #
8:00 am – 9:00 am	cell 4
9:00 am – 12:30 pm	cell 9
12:30 pm – 13:30 pm	cell 5
13:30 pm – 16:00 pm	cell 2
16:00 pm – 17:00 pm	cell 3
17:00 pm – 19:00 pm	cell 5
19:00 pm – 22:00 pm	cell 5
22:00 pm -	cell 4

Figure 3-3: UMH of a MU "John"

Of course, in the real world, a user could not be that on time. Although the work hour is from 9:00 am to 17:00pm, not every body arrives at office at the same time. Nor a person always goes to his office at exactly the same minute every weekday. Actually, no mater John gets office at 8:55am or 9:05am. We consider it the same. John arrives at office 9:00 am. Later in this chapter, when we talk about at an exact time, it means in a small range of time around the given time.

If we consider John's movement shown in Figure 3-2 as a function, then we can interpret it in a coordinate.

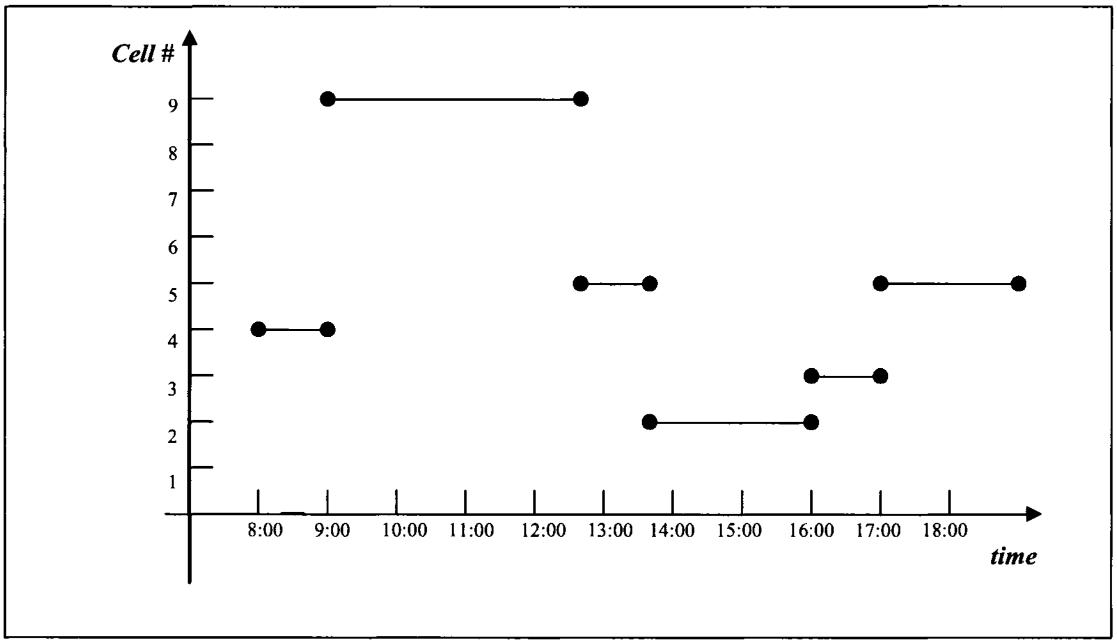


Figure 3-4: Function of John's Movement

Figure 3-4 is just a diagram of the movement of John, not a profile. As a profile, we mean to draw a point every 30 minutes, then we get Figure 3-5.

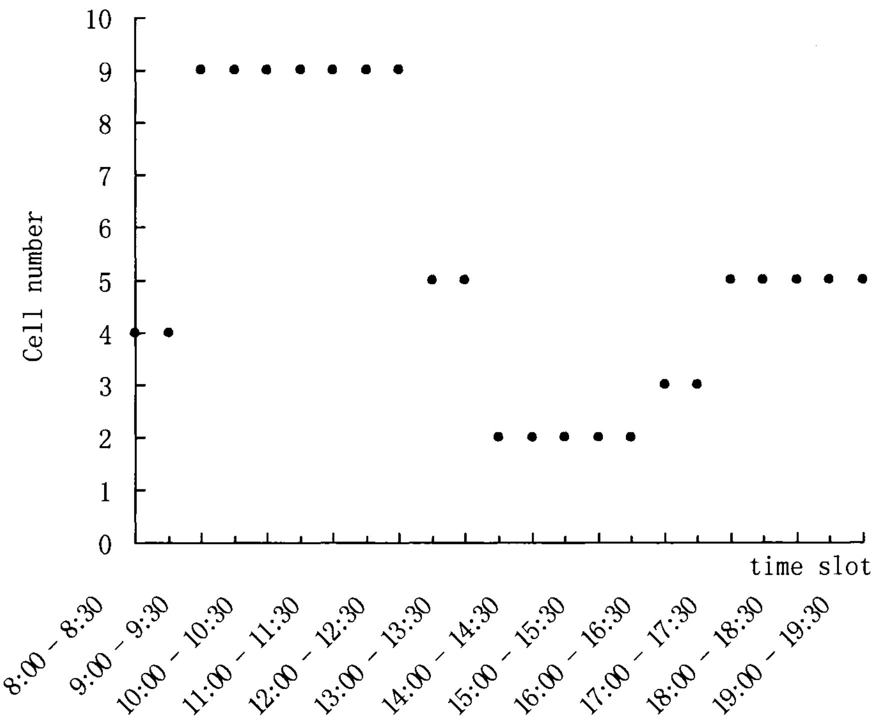


Figure 3-5: portrait based on profile

It is easy to see that Figure 3-4 and Figure 3-5 are identical, which implies that it is perfect to take a sample every 30 minutes to John's profile. And we get the profile as (4, 4, 4, 9, 9, 9, 9, 9, 9, 9, 5, 5, 2, 2, 2, 2, 2, 3, 3, 5, 5, 5, 5, 5, 5, 4). Obviously, such a profile is regarded as array in computing, and is much easier for a computer to memory, study, and analyze.

3.2.2 Build a User Profile

In this section, we discuss about how to build a user profile. With the same example as in section 3.2.1 we draw a grosser path of John's movement just for the purpose of a simpler example. The sample path draws a point every 2 hours, instead of 30 inputs.

And the new path vector we get is h = (4, 9, 9, 2, 3, 5, 5, 4). Let's draw the graph G in figure 3-6.

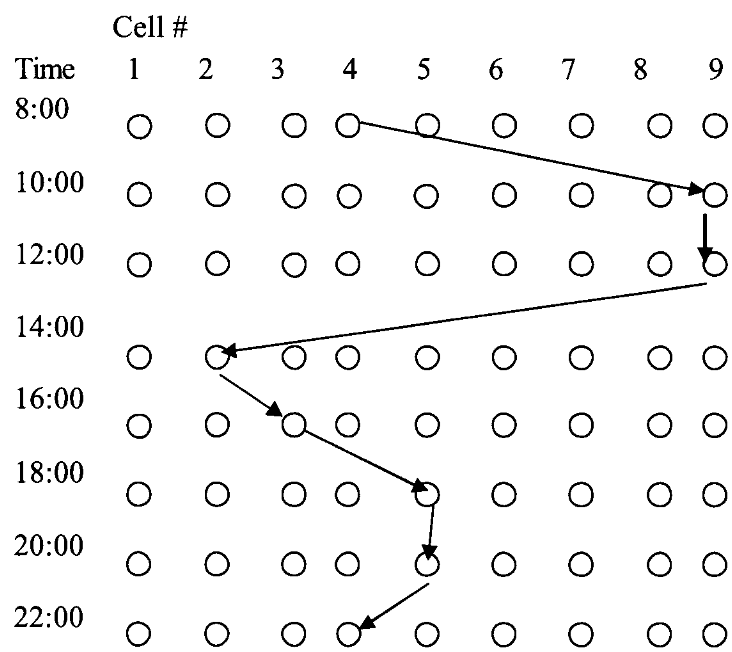


Figure 3-6: Graph G - a Path

To build John's profile based on his movement in week, we need to trace his paths from Monday to Sunday, and name the seven traced path as H_i (i = 1, 2, 3, …, 7) respectively. Assume the paths we get are as in Figure 3-7.

H1 = (4, 9, 9, 2, 3, 5, 5, 4)
H2 = (4, 9, 9, 2, 9, 9, 6, 5)
H3 = (4, 9, 9, 2, 9, 9, 7, 3)
H4 = (4, 9, 9, 2, 9, 9, 5, 5)
H5 = (4, 9, 9, 2, 5, 5, 5, 4)
H6 = (4, 4, 4, 4, 5, 5, 5, 4)
H7 = (4, 2, 3, 4, 5, 5, 5, 4)

Figure 3-7: Paths of a Week

If we draw the 7 paths as a weighted graph, then we get Figure 3-8. It shows that, at time T1 (8:00am), if a MU's current position is in cell 4, then in the following time durations (T2 – T7), the probability distribution which it will go to the next cells. The weight in this graph is the number of states transformation occurs in a week. For example, at 8:00 am, the MU normally, was in cell 4, and it went to cell 2 once in the week, and once to cell 4, 5 times to cell 9. In the real world, the data needed to build a profile graph could be the paths of one year, which would be more complex than this sample.

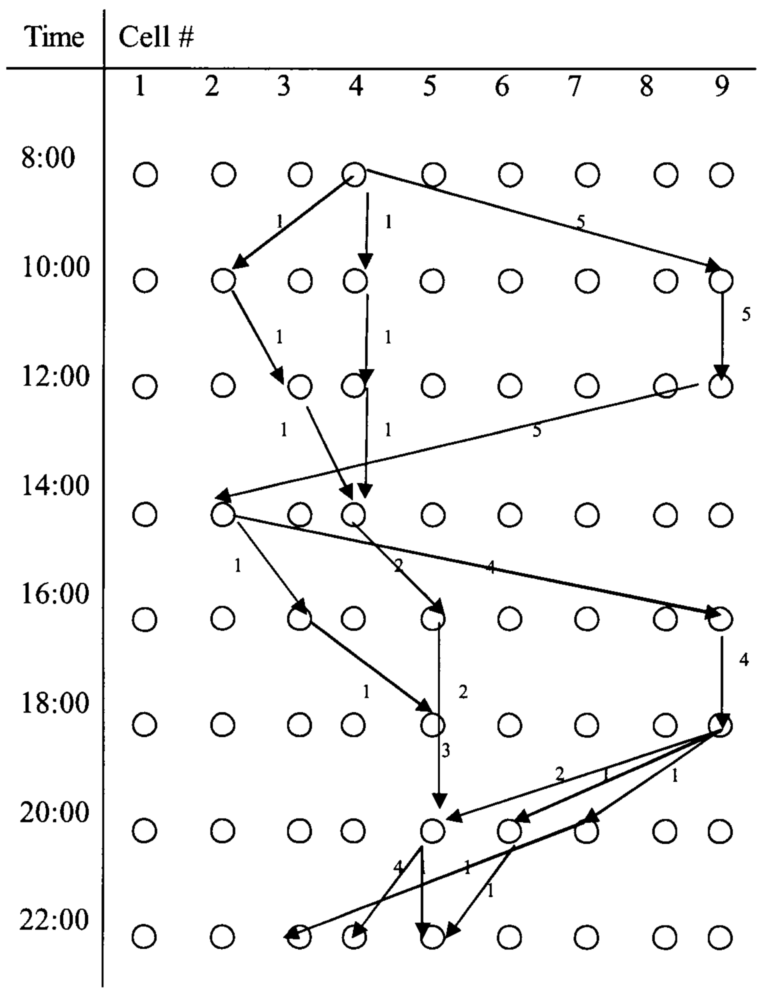


Figure 3-8: Graph of Path

With the weighted graph, we are very close to the user profile. In the last step, we change the weight into probability with the following formula Eq. (3.1), and we get the final profile of John in the example. See Figure 3-9.

$$a_{ij} = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}} \tag{3.1}$$

Where, a_{ij} means at some time t, the probability that from cell i to cell j, (n = 9 in our example)

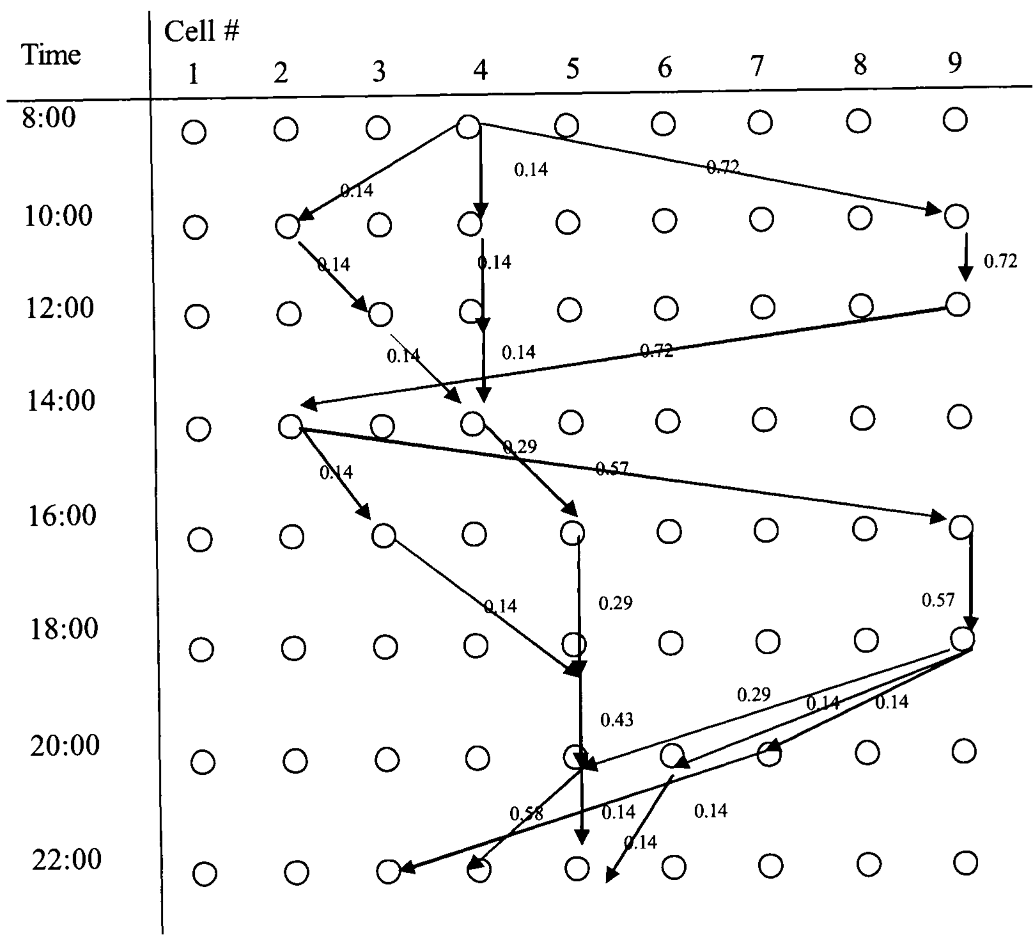


Figure 3-9: weighted graph of paths

3.2.3 Prediction Matrix Algorithm (PMA)

In this method, with a weighted graph, after a breath-first searching in the tree we obtain the best gain, which is the most possibility path for this MU. And then the result will be used for generating the Prediction Matrix, in which, the elements presents a probability at some time for a MU from one cell to another. Finally after some Matrix operation, we will obtain the right states of the MU.

Before presenting PMA, we first give some formal definitions.

<u>Breadth-First Search(BFS)</u>

The breath-first search algorithms search a state-space by constructing a hierarchical tree structure consisting of a set of nodes and links. The algorithms defines a way to move through the tree structure, examine the values at nodes in a controlled and systematic. From the start, it loooks at each node on edge away. Then it moves out from those nodes to all nodes two edge away from the start, Breath-first search is complete; it will find a solution if one exists. In a short, Breadth-first search visit all adjacent vertices before going deeper, then go deeper in one of the adjacent vertices.

Table 3-1: BFS Algorithm

```
Algorithm BFS(Vertex s)
initialize container L0, level, to contain vertex s
i = 0
while Li is not empty do
        {create container Li+1 to initially be empty          // next level
        for each vertex v in Li do                 // vertices in previous level
                for each edge e incident on v do
                        if edge e is unexplored then
                                let w be the other end of e
                        if vertex w is unexplored then
                          label e a discovery edge and  insert w into Li+1
                        else
                          label e as a cross edge
        i = i + 1
} // end while
```

Path

A user moving between two locations in cellular network generates a path. We define a user's *path* as a sequence of location cells. For example, if the user moves from c1 to c5 through c3, then the path is represented as path (c1, c3, c5).

The Parameters of the PMA Algorithm

- L_k - User's current location, is defined as the measured coordinates (day and time) by a system
- t_k - Represents the current time for a MU
- T - Time period, is defined as the time duration of a learning / prediction period, here, let's say 12 hours
- s - State vector, the current state of a subscriber, cell location. For example, $S1(0, 0, 0, 1, 0, 0, 0, 0, 0, 0)$, means, the mobile terminal is in cell 4 at time t_1.
- S - Set of all the s
- H - a path in the learning tree
- M_k - Probability Prediction Matrix, at time t_k,
- a_{ij} - the weight in the learning tree

So given the current location (L_k, t_k) and T, the problem of location prediction is to estimate location L_{k+1} at time t_{k+1} or t_{k+T}. From the graph, we can deduce a probability matrix M_k (p, t_k), which presents the mobile user will move from cell c_i to c_j at some time t_k.

The traversing of graph will give us a tree in the end. See Figure3-10. We linked the nodes

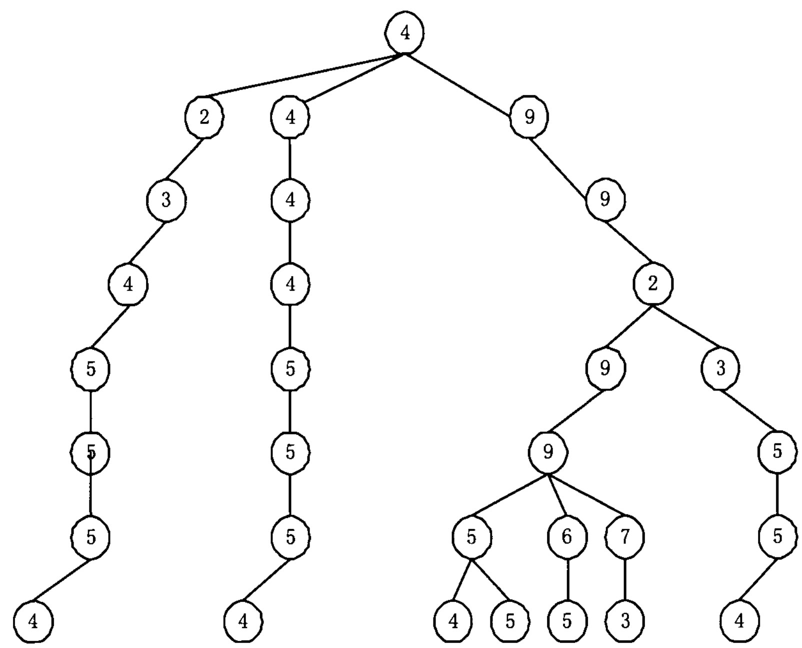


Figure 3-10: a sample of the tree structure

Apply the weight to this tree in Figure 3-10. Then we get a learning tree. In case the graphic produces more than one tree, it's the situation that at the beginning time t_1, the MU could stay in different cell with the almost same possibility. We can simply add a virtual root mode and merge them into one tree. In the tree, the decision is made according to the weight, which means the maximum weight branch has the privilege to visit than others, that is to say, the most possibility path the MU will take. See Figure 3-11.

When deducing a subscriber's current location, we begin from the root of the tree, and go along the branch that has the biggest weight. As in the example, we can expect John's path to be path = *(4, 9, 9, 2, 9, 9, 5, 4).*

We define a probability matrix $M_k(p, t_k)$, represents the probability that the MU will transfer from states S_k to S_{k+1} at time t_k. And p_{ij}, the value of M_k, represents the probability of the MU transfer from cell i to cell j, by that time. We define the probability matrix M_k (p, t_k), then for row i, column j, the element in the matrix, p_{ij}, presents a probability from cell i to cell j at time T_i. so for the p_{ij}, we have,

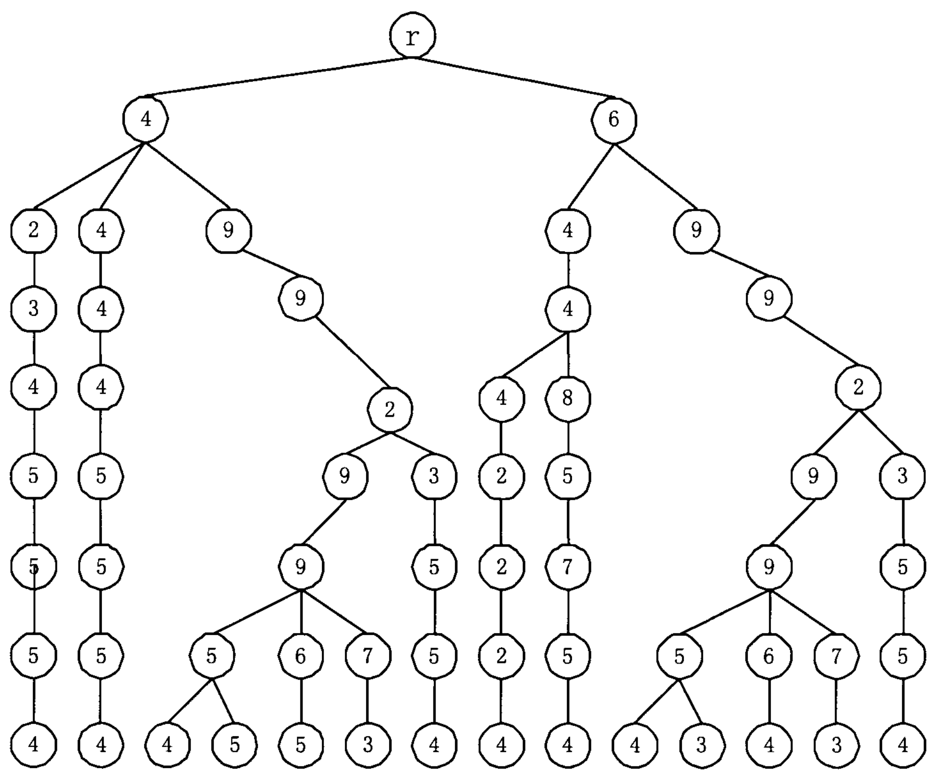


Figure 3-11: tree structure with multiple roots

In the example of the last section, we can use the graph in Figure3-11 to build probability matrix to figure out the subscriber's location for the accurate profile. In Figure3-11, we assume there are the links to connect with each node pair between two neighboring rows. The weight with line is the possible probability value from a state to the other state, while the weight is zero if there is no line connection actually. Then we can design the probability matrix M_1, M_2, …, and M_n, n is the number of the time slot, here we define 7 time slots for example, which tell the possibilities transferring from any previous state.

$$a_{ij} = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}} \qquad \text{(n = 9 in our example)} \tag{3.2}$$

As a matter, here we give M_6 as an example.

$$M6 = \begin{vmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{4}{5} & \frac{1}{5} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{vmatrix}$$

3.3 Movements Prediction

Before apply the PMA to predict the future states, we firstly remark the conditional probability, two events, A and B, A assuming that B has occurred, denoted, P (A/B), equals

$$P(A/B) = P(AB)/P(B) \qquad P(B) \neq 0 \tag{3.3}$$

Then,

$$P(AB) = P(B)\, P(A/B) \tag{3.4}$$

If A and B are independent, we have,

$$P(A/B) = P(A) \tag{3.5}$$

Then,

$$P(AB) = P(A)\,P(B) \tag{3.6}$$

A presents event from state i transfer to state j; B presents event from state j transfer to state k; Then P(AB) presents event from state i transfer to state j, and then from state j transfer to state k.

Based on this probability theory, we apply to the algorithm of PMA, described in the last section, then we can predict the future states of a subscribe during his mobile movements. If we know a states *S* and the probability matrix *M* at that time, we can get the probability of the next states P, by multiply *S* and *M*.

The Predict Matrix Algorithm is described as the following:

Begin

Input a integer n

input a vector, S, t

input learning tree matrix, M,

if (S is not empty and M is not empty)

then

i =1; j=1;

while(i<n, j<n)

do $(P_j = S_i \prod_{k=i}^{j-1} M_k)$

i++; j++;

end

for (m = 1,m<n, m++)

output P_m

end

End

Here we give example for a detail illustration, given a current state S_1, for the next predictive state P_2, we have,

$$P_2 = S_1 \times M_1 \tag{3.7}$$

And then, we may obtain the following states respectively,

$$P_3 = s_1 \times M_1 \times M_2 \tag{3.8}$$

$$P_4 = s_1 \times M_1 \times M_2 \times M_3 \tag{3.9}$$

$$\ldots$$

$$P_8 = S_1 \times M_1 \times M_2 \times M_3 \times M_4 \times M_5 \times M_6 \times M_7 \tag{3.10}$$

And for any medium states S_k, we also can predict any future states. For example, we know S_4 , for P_7, we have

$$P_7 = S_4 * M_4 * M_5 * M_6 \tag{3.11}$$

Apply the above formula to the general case, we can learn that with any given states S_i, for any predictive status P_j, we have,

$$P_j = S_i \prod_{k=i}^{j-1} M_k \tag{3.12}$$

After we get the result which is a probability to some cell, we still need to know what the exact location is. So for the value of the state probability P, we will do a transformation. Among all the values, we find the maximum and let it be 1, and for all the other value let them be 0. With this transformation, we get a new vector, S_{next}, that is what we need, the output vector, the next state at which the mobile terminal will stay. See the algorithm of transformation:

```
Begin
Input n,P,
For i = 1, n
d = Maximum p[i];
For (i =1, i <10 , i++ )
   If i = d
   Then  p[i] =1;
    Else  p[i] = 0;
End
```

3.3.1 Location Determination

To estimate the possibility from the given state to a future time, we can give a state vector s, $s = s[n]$, where n is the number of the cells in a town/city. It presents the current state of a subscriber at some time period. And the value of the elements in S is *0* or *1*, *1* for in the cell, while *0* for not in the cell. In our model, we have only 9 cells in question, so we define 9 elements in the vector array.

For example, S_6 = [0, 0, 0, 0, 1, 0, 0, 0, 0, 0]. Which means the subscriber is in cell 5 at time t_6 (8:00pm). We multiply this vector with the probability matrix M_6, and then we get an output as probability vector P_7. For example, if John is at cell 5 at 8:00pm. And we want to know the probability of the cells that John might be at 10:00pm, and then we can do

$$S_6 = \begin{vmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{vmatrix}$$

$$M_6 = \begin{vmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{4}{5} & \frac{1}{5} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{vmatrix}$$

$$S_5 \times M_6 = \begin{vmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{vmatrix} \times \begin{vmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{4}{5} & \frac{1}{5} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{vmatrix}$$

$$P_7 = \begin{vmatrix} 0 & 0 & 0 & \frac{4}{5} & \frac{1}{5} & 0 & 0 & 0 & 0 \end{vmatrix}$$

$$S_7 = \begin{vmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{vmatrix} \text{ (After transformation)}$$

That means, the next state S_7, that is to say, at the time 10:00pm, the mobile terminal will locate in cell 4.

3.3.2 Path Determination

According to the principium expounded above, we can obtain the predictive locations, those are the cells in which the mobile terminal will resident. Collect all these cells for the subscriber in time order, then a list comes out, that is his/her tracking path during the observation time period. In detail, if we begin with an original state of a mobile terminal, s1, during a time circle, as we supposed, from tl to t9 (8:00am – 10:00 pm), with the corresponding probability matrix, P1, P2, ..., P6, apply Formula (3.1) - (3.4), finally we can every state during the time period in question. And the set of the state will be the profile of the mobile terminal, also the tracking path.

3.3.3. Problem issued

There is a problem in using the profile. That is, how about if the subscriber is in an unknown state? In such a case, which means it may receive an illegal input in the algorithm, the IS-41 scheme is launched, and a new trace is applied to learn and update the existing profile. See Figure 3-12 for the flowchart.

3.4. Location Management Scheme

Two main procedures are used in the IS-41 location management scheme: location update and location search. A location update occurs when a MU moves to a new LA; a location search occurs when a fixed or mobile host wants to communicate with a MU whose current LA is unknown. In IS-41, the HLR is queried every time a location search or update is performed which results in tremendous strain on the use of the network resources as the number of PCS subscribers increase. The proposed scheme will perform the same location update and search procedures. The detailed description of the two procedures is expounded in the following sections.

3.4.1 location Update

1. When a MU enters a new LA, it sends a registration message to the MSC/VLR through the base station.
2. The MSC of the new LA area registers the MU with its associated VLR and sends a registration notification message to the HLR via the signal transfer point (STP).

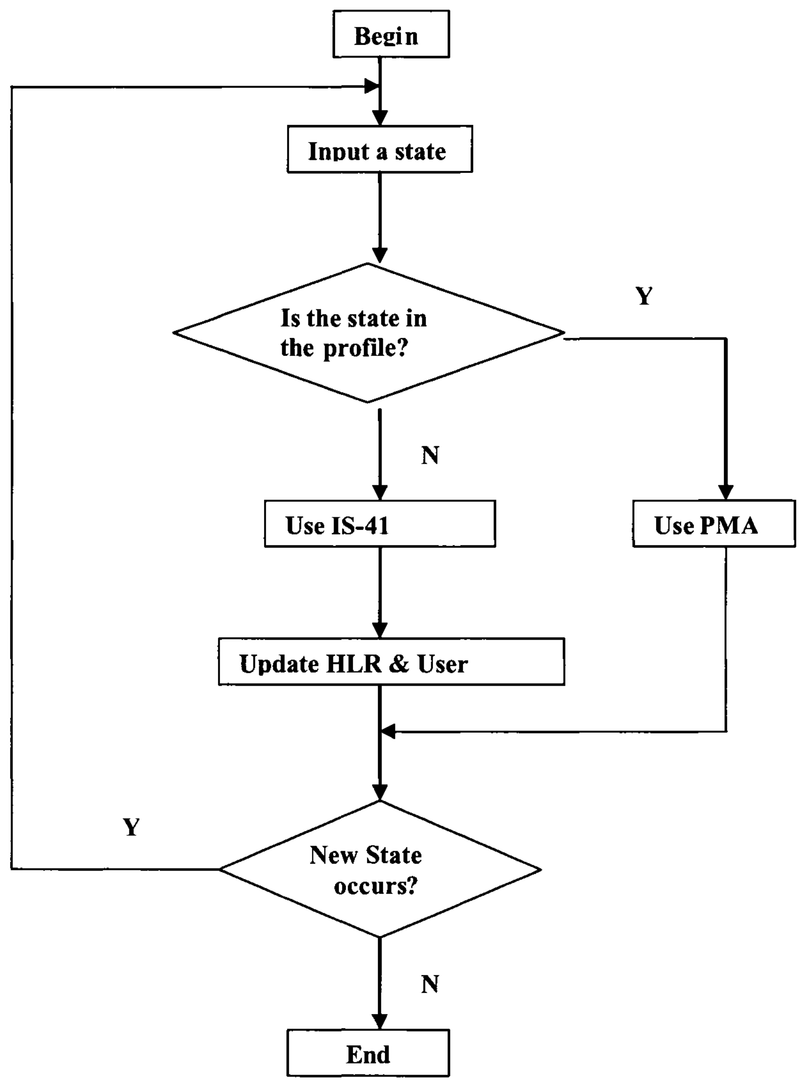


Figure 3-12 : The flowchart of the missing algorithm

3. Based on the MU's identification number, the SSTP executes the global title translation (GTT) procedure to determine the HLR of the MU. The corresponding message is then forwarded to the HLR.
4. The HLR send s registration cancellation message to the previous MSC/VLR.

5. The previous MSC deletes the MU's profile in its associated VLR and sends a cancellation acknowledgment message to the HLR.
6. The HLR acknowledges the location update by sending an acknowledgement to the new MSC/VLR. The HLR normally provides the profile of the MU in this message. When the new MSC/VLR receives the message, it starts providing service to the MU.

3.4.2 location Search

1. Any incoming call from a mobile or fixed unit (identified as A) to a MU-B is received by an originating MSC/VLR (called the source MSC/VLR).
2. The source MSC/VLR sends a location request message to the HLR of the called MU via the STP.
3. The STP uses the GTT procedure to determine to which HLR the message must be forwarded.
4. Upon receipt of the message, the HLR determines that the call is for MU-B and sends a routing request message to MU-B's current MSC/VLR (destination MSC/VLR).
5. When the destination MSC/VLR of MU-B receives the message, it allocates a temporary location directory number (TLDN) to the source the HLR.
6. The HLR repays the TLDN to the source MSC/VLR.
7. Finally the source MSC/VLR routes the call to the destination MSC/VLR.

3.5 Analytical Model

In this section, using the location update and search cost, we analytically compare the IS-41 scheme with the proposed scheme. We use a cost formulation for the computation of update and search costs. This formulation allows for the comparison of the signaling cost and the database accesses of two schemes.

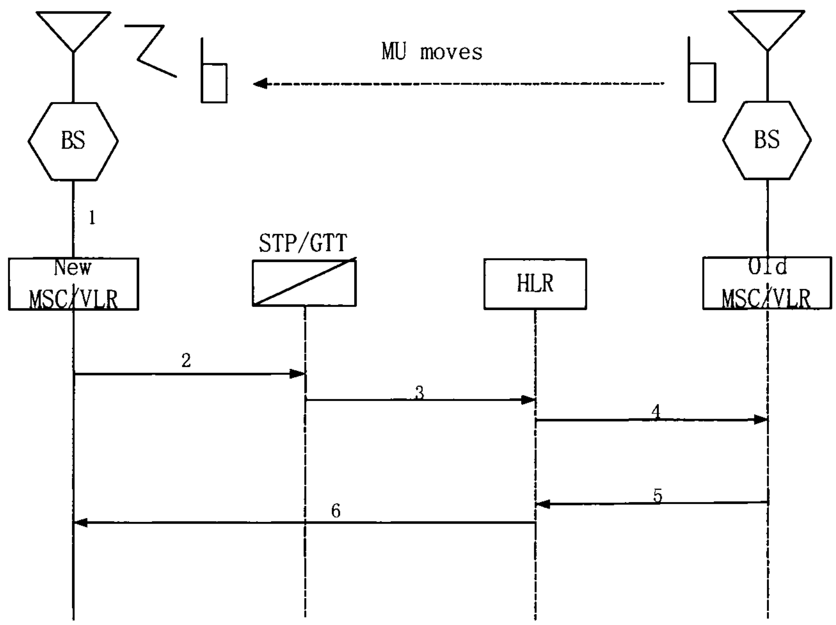


Figure 3-13: Location Update Procedure

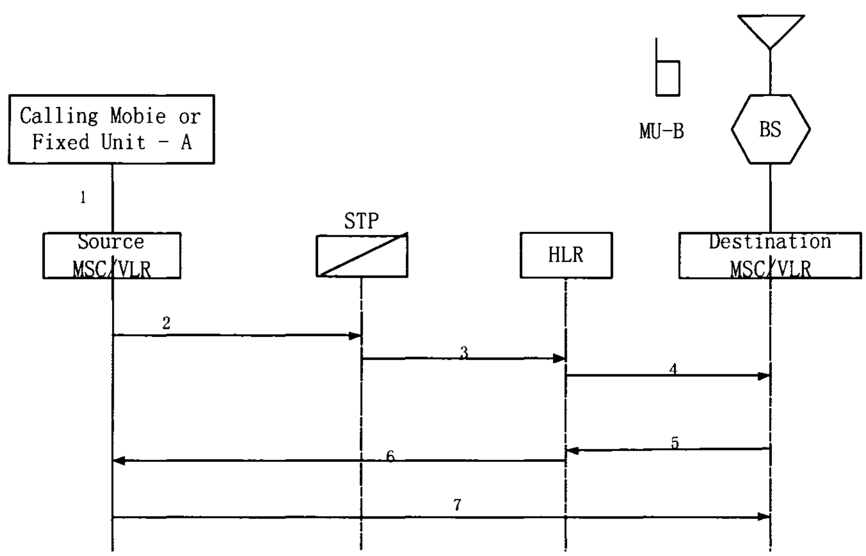


Figure 3-14: Location Search Procedure

When calculate costs, we use the same parameters as database access cost, communication cost, *p,* and *q*. Database cost consists of the HLR, the MSC/VLR access cost.

Communication cost consists of the costs for sending a message through the local A-link, the D-link, and the remote A-link.

The Local A-link : Connect the LSTPs to their associated Mobile Switching Centers and VLRs.

The Remote A-link : Connects the HLR to the RSTP.

The D-links : Connect the RSTP to the LSTPs.

3.5.1 Cost Parameters of the Reference Signaling Network

We define the cost parameters to be as follows:

Dh - The cost for accessing the HLR.

Dv - The cost for accessing the VLR.

Rc - The cost for sending a message through the D link.

Lc - The cost for sending a message through the local A link.

Hc - The cost for sending a message through the remote A link.

p - Probability that mobile terminal moves the in same LSTP(inter)

q - Probability that mobile terminal moves in different LSTP(intra)

r - Probability that calling and called mobile terminal reside at the same LSTP.

c – Number of the incoming calls, which used for the cost comparison of IS-41 scheme to PMA.

3.5.2 IS-41 Scheme

In this section, we analyze the cost of the IS-41 location management scheme for the collocated MSC/VLR configuration.

The cost of IS-41 scheme is from two aspects: Location Update and Location Search. Location Updates happen when there is a handover, or a time based handoff. Location Search occurs when there is an incoming call, and the MU is not found in the recorded cell.

The mobile location update cost consists of cost of update the new MSC/VLR, cost of canceling the old MSC/VLR, cost of update the HLR, and cost of signaling between the MSC/VLR and the HLR. The location update cost per move incurred by the IS-41 scheme is given by Eq. (3.13)

$$U_{IS} = Dv + Dh + 4(Lc + Rc + Hc) \tag{3.13}$$

The mobile terminal location search cost incurred by the IS-41 standard consists of cost of search the HLR, cost of search the MSC/VLR, and the cost of the associated signaling. The location search cost per call incurred by the IS-4 1 standard is given by Eq.(3.14).

$$Q_{IS} = Dv + Dh + 2(Lc + Rc + Hc) \tag{3.14}$$

3.5.3 Proposed scheme

In this section, we analyze the cost of the updating and search procedures proposed in our scheme. The cost of PMA is also composed of the two factors. But the Location Update is rarely happened in the PMA scheme, as the algorithm tells which the next cell to go is. However, if the MU falls in a cell that has no reference in the Predictive Matrix, then the IS-41 scheme is called temporarily until the record is found after time.

<u>For the location update cost</u>

$$U = Dv + Dh + 4(Lc + Rc + Hc) \tag{3.15}$$

In theory, our cost on location update should be same as the IS-41 scheme, but in fact, with the profile-based location management, when the probability of the movements model change is very small, the cost on the location update is **0**. So we don't need to do the location update actually.

For the location search cost

It consists of the number of database access and communication cost. Database access cost consists of the new MSC/VLR, the HLR search cost. Communication cost consists of the costs for sending a message through the local A-link, the D- link, and the remote A-link. The location search cost per move incurred by the proposed scheme is also same with in the IS-41 scheme, given by Eq.(3.16).

$$Q = Dv + Dh + 4(Lc + Rc + Hc) \tag{3.16}$$

The total cost of a location management scheme depends on the location updating cost and the location search cost of that scheme. In order to be able to estimate the total cost, the rate of call arrivals at a mobile, ?c, and the rate at which the mobile moves between registration areas, ?m, are needed. Total cost, *T,* is computed as shown in Eq.(3.17),

$$\left\{ \begin{array}{l} U = \lambda m U, \\ Q = \lambda c Q, \\ T = U + Q \end{array} \right\} \tag{3.17}$$

Where U and Q represent the location updating cost per move and location search cost per call, respectively.

Since the main objective of the proposed scheme is to improve the performance over the IS-41 scheme, we define the cost to be the ratio of the total cost in the scheme to that of total cost in the IS-41 scheme. The cost of a scheme is given by E.q.(3.18).

$$T = (\lambda mU + \lambda cQ) / (U_{IS}\, \lambda m + \lambda c\, Q_{IS}) \tag{3.18}$$

In most of the theory research, the CMR (Call-to-Mobility Ratio) is used to study the performance of the proposed scheme on cost reduce. Using this definition of CMR, the cost *T,* is given by (3.19).

$$T = (U+pQ)/(U_{IS} + p\, Q_{IS}) \tag{3.19}$$

Where, $p = \lambda m/\lambda c$

3.6 Summary

With this user profile, we can get a location prediction on the subscriber. And many methods based on user profile will get a good implementation in reducing the cost of location update and paging, which is our common objective on wireless telecommunication networks of 3G.

In the following chapter, we will show the simulation result and discuss the performance evaluation of the proposed method.

Chapter 4
Performance Evaluation

For an efficient implementation of the proposed scheme, namely, the PMA, the simulation model is requested in order to estimate its performance. Section 4.1 describes the system environments. In section 4.2, a detailed description of the simulation design is given, the input and output parameters are defined. The system model includes the framework architecture and mobility model follows in section 4.3. Finally, the simulation results are presented and analyzed in the section 4.4.

4.1 Simulation Environment

The main objective of the simulation model was to provide a neutral, systematic analysis of the performance of the Predictive Matrix Algorithm, and to gain a deeper insight into the inherent characteristics of this profile-based location management. This section presents a discussion of the simulation environment, framework and the analysis of the mobility model.

4.1.1 Topology

Our simulation topology models a city mapped in an area of $10000 \times 10000m^2$. The city is divided into 100 cells. Mobile users can move within and in between the cells.

As assumption, the people of the city are all living in the area of radio coverage. There are residence, offices, shopping malls, hospitals, schools, and so on. All the residents can find every thing they need, hence they only live in the city and never leave. Everybody in the city has a cellular phone to keep communicated with others. Most of the residents act in regular, for example, an office worker, a professor, a college student. And some people have the random movements, for example, a salesman. So, we design the mobility patter as routine and random two classes in our simulation. And all our simulation results can easily scale to larger area.

4.1.2 A General Framework for Analysis

The architecture of the learning network given in Figure 3-1 assumes that the HLR and the VLRs communicate through a Regional Signaling Transfer Point (RSTP) and the LSTPs. A message between the HLR and a VLR may go through several intermediate switches inside the connection network before reaching its destination. The cost for transfer a signaling message between the HLR and different VLRs may vary. According to Figure3-1, there are three types of connection among the network elements. The Remote A-link connects the HLR to the RSTP, the D-links connect the RSTP to the LSTPs and the local A-links connect the LSTPs to their associated Mobile Switching Centers and VLRs[13,15,18,19,].

In this section, a new mobility modeling framework [20] is used to evaluate the performance of the proposed scheme. The core of the modeling framework is a mobility model aiming to reflect the actual user movement behaviors. In most of the previous studies, a single movement pattern such as random walk has been assumed. In reality, a user may change higher movement patterns often, even on a daily basis. For example, the user may spend considerable time periods within attraction sites (being stationary or performing random walks) while making long-distance or short distance trips (directional movements) occasionally. When the user travels, he/she usually has a destination in mind so a unique random walk model is not suitable for modeling a directional trip. We propose the system model as in Figure 3-1.

4.1.3 Mobility Model

There are two kinds of mobility model used in our simulation model.

A mobility model resolves the problem of imitating the actual movements of the networks in the real world. To build such a model, the most straightforward way is to trace the movements of the stations in a real network and then abstract the moving pattern. In this way, the movement of a large number of stations has to be observed for a long time, to gain useful information.

Another mobility model proposed by T. Camp et al. [21], the synthetic model, imitate actual mobility models as close as possible.

4.2 Simulation Design

The simulation of the Predictive Matrix Algorithm is based on C++ language programs. In the first phase of the simulation, the programs imitates the behavior of a MU with in the range of a small cellular network, traces the movements of the MU, learns its mobility pattern, and builds the Predictive Matrix. In the second phase of the simulation, the programs apply different Location Management strategies, namely the IS-41 and the PMA, and compare the management cost of each individual scheme.

4.2.1 Assumptions

The simulation is based on the following assumptions:

- The Mobile Units move only inside the object cellular network, and never escapes.
- The MU set is predefined; no MU leaves or joins the MU set during the period of experiment.
- The MU is extremely independently, which means it decides its movement, including the direction and speed, without outside interferences.
- Data and control messages have the same priority.
- The network bandwidth is enough to handle the requests of MUs inside the object cellular network.

4.2.2 Input Parameters

The following input parameters are required in the simulation:

- Cellular network: The object cellular network is mapped in an area of $10000 \times 10000m^2$, in which there are 100 cells.
- Cells: To facilitate the simulation, a cell is shaped in a $1000 \times 1000m^2$ square.
- Mobile Unit: A Mobile Unit (MU) in the network is represented by a point MU(x, y).
- Direction of MU: Each MU moves at a direction randomly selected from any 1 out of 360 degrees. The direction changes every 1 second.
- Speed: Totally random speed, ranged from 0 to 30km/hour.
- Handoff: Two handoff modes are considered in the simulation, time based handoff and signal strength based handoff.
- Location Update: Once there is a handoff, there is an immediate location update (in the IS-41 scheme), hence there are actually two location update modes – time based, and handover based. No location update required as in the PMA scheme.
- Evaluation Term: 20 working days, or 4 weeks.
- Incoming calls: Ranged from 0 per day to 40 per day. The more incoming calls, the higher the Call to Mobile Ratio (CMR).
- Mobility pattern: Routine movement and totally random movement.

4.2.3 Output Parameters

First simulation phase output:

- Trace.txt file, which records the MU's yearly movement traced by every 30 minutes.
- Predictive Matrix M, which is a $24\times100\times100$ integer array in the runtime.

Second simulation phase output:

- Digital results in pure text files that record the cost of different Location Management schemes under various conditions.

4.2.4 Simulation Procedure

4.2.4.1 Trace the movement of a Mobile Unit

In the beginning of the simulation, an area $10000 \times 10000m^2$ is allocated to the object cellular network. Inside the network, one hundred cells are equally distributed, which spans $10000 \times 10000m^2$ each. The cells are assigned sequence numbers, from 0 to 99, to imitate the cells' IDs in the real world. A Mobile Unit in the network is represented by a point MU(x, y), where (x, y) stands for the MU's position in the coordinate. The MU independently selects its moving direction and speed. One second is defined as the length of a time slot. In a time slot, the MU moves along only one direction with an even speed. To trace the movement the program calls the method Cell (double, double) every 30 minutes' simulation time to identify which cell the MU is in. Figure 4-1 is the Cell (double, double) method source code in C++.

```
Cell(double x, double y)
        for (i=0;i<days;i++)        //10 days
         {x=y=750.0;                //home location
           for (j=0;j<=HOUR*12;j++)        //trace 12 hours' movement
             {direction=(rand()*100l/RAND_MAX)*3.6;
                x+=speed*cos(direction);
                y+=speed*sin(direction); //if out of range, turn back
                if(x<0) x=-x;
                if(y<0) y=-y;
                if(x>1000) x=2000-x;
                if(y>1000) y=2000-y;
                if ((j%(MINUTE*30))==0)    //trace MU every 60 minutes
                  { cell=Cell(x,y);
                   fout<<cell<<"\t";}
                }
                fout<<endl;       //change line
        }
```

Figure 4-1: Cell method in source code

The trace results are preserved into trace.txt, and called by the program. The program reads the traced results, and processing them with an iterative method to obtain the Predictive Matrix. The source code of the method is as in Figure 4-2.

```
fin.open("trace.txt");      // open trace file
  if (!fin )                  // if cannot open trace file
    { cerr << " Could not open input file: " << "trace.txt" << endl;
      exit( 1 ); }
  for (i=0;i<days;i++)
      { for (j=0;j<24;j++)
            { fin >>next;
              if (j==0)
                 {current=next;
                  fin>>next; }
                  WeightMatrix[j][current][next]++;
                  current=next;
            }
      }
fin.close();
```

Figure 4-2: Trace method in source code

4.2.4.2 Cost Comparison

The cost of IS-41 scheme is from two aspects: Location Update and Location Search. Location Updates happen when there is a handover, or a time based handoff. Location Search occurs when there is an incoming call, and the MU is not found in the recorded cell. The cost of PMA is also composed of the two factors. But the Location Update is rarely happened in the PMA scheme, as the algorithm tells which the next cell to go is. However, if the MU falls in a cell that has no reference in the Predictive Matrix, then the IS-41 scheme is called temporarily until the record is found after time.

Without an incoming call, there is no need for a Location Search. The more there are incoming calls, the higher the possibility to produce greater management cost. Incoming calls in the simulation is random distributed. Upon an incoming call, the Cost() method checks the availability of the MU and calculate the cost generated. The Cost() function is shown as in Figure 4-3.

```
for (i=0;i<days;i++)        //10 days
  {time=TIMER;
   called=Calls;
   LU=LS=PLS=PLU=0;
    current=1973;
    begin=0;
    max=0;
    x=y=750.0;                  //home location
   cell=reg=move=next=Cell(x,y);
   for (j=0;j<=HOUR*12;j++)        //trace 12 hours' movement
     {time--;
       direction=(rand()*100l/RAND_MAX)*3.6;
       speed=(rand()*100l/RAND_MAX)/30;      //10km/h
       x+=speed*cos(direction);
       y+=speed*sin(direction);            //if out of range, turn back
       if(x<0) x=-x;
       if(y<0) y=-y;
       if(x>1000) x=2000-x;
       if(y>1000) y=2000-y;
       if (reg!=Cell(x,y))
        {LU++;
         reg=Cell(x,y); }//Learning scheme update location every 30 minutes
         if ((j%(MINUTE*30))==(MINUTE*30-1))
              {for (k=0;k<100;k++)
                {if (WeightMatrix[begin][move][k]>max)
                     {max=WeightMatrix[begin][move][k];
                       next=k; }
```

```
            }
            begin++;
            if (max==0)
              {move=Cell(x,y);
                    PLU++;}
            else
               {move=next; }
            max=0;
      }
      //Call in or out
      if ((j==current)&&(called>0))
        {current=current+HOUR*12/Calls;
           called--;
            cell=Cell(x,y);
            if (reg!=cell)
               {LS++;
                time=TIMER; }
            if (move!=cell)
              {PLS++;
               move=cell; }
        }
   }
      IS=LS*6+LU;
      PF=PLS*6+PLU;
      fout<<IS<<"\t"<<PF<<endl;
}
```

Figure 4-3: Cost function

4.3 Numerical Results

To evaluate the performance of the model, we performed computations using various values for c, which is the number of the incoming calls used for the cost comparison of IS-41 scheme to PMA approach. Several scenarios have been considered as the following.

4.3.1. Handoff-based

We first consider in case of location update happens when handoff. From Figure 4-4, it is very obvious that the cost of IS-41 is much higher than in the scheme PMA. In this case of handoff-based, location update happens so frequently that it costs too much, around 150 cost units. So it's not idea condition for our study on cost comparison.

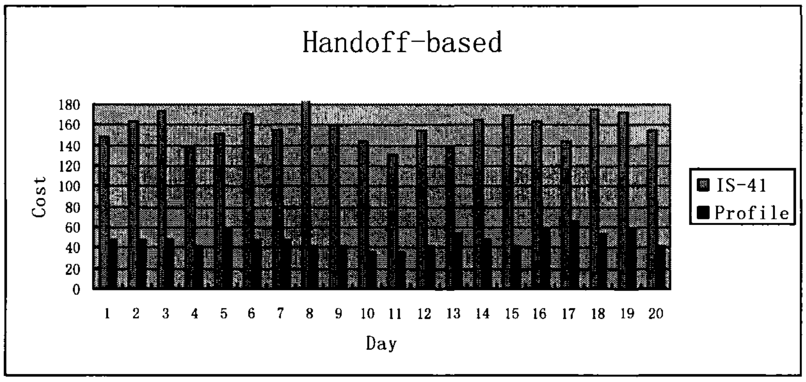


Figure 4-4: Relative cost for handoff-based

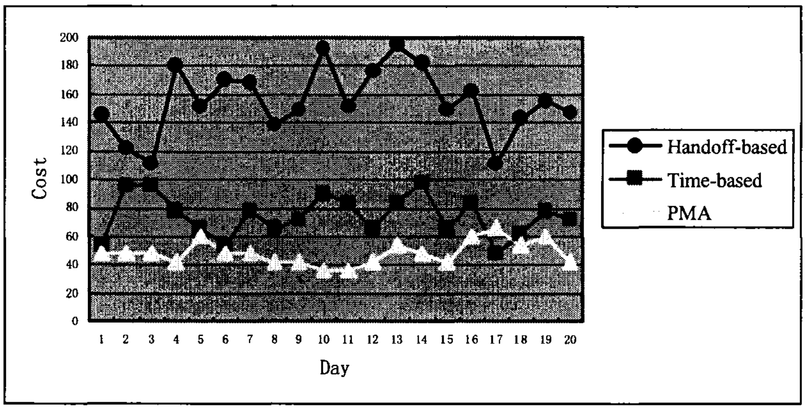


Figure 4-5: Cost Comparison for handoff-based, time-based, PAM

Figure 4-5 is a demonstration on comparison between handoff-based, time-based and PMA. By observing the results in these three situations, we can find that, the PMA scheme always has the better performance than IS-41 scheme. That is the key point that we want to expound. Because most of the people have the regular movements activities, and it's possible to build a profile based on their daily behavior. With the routine profile, location update will rarely happen and location search will also be saved at some extent. That is the contribution of we propose scheme. And from Figure 4-5, we also found that handoff-based update cost much more than time-based did. So in the rest of this chapter, we will use time-based location update. And the cost comparison will be done between PMA and time-based.

4.3.2. Time-based

To be explicit, in the scenario time-based, location update is performed in every 30 minutes or by resetting the timer. In the case of time-based, we also have two kinds of model. One is the random movement, the other is the routine movement.

1. Movement by Random

In figure 4-6, it shows that, by random movements based on time, when the number of incoming calls c, is 25, IS-41 has the much higher cost than in PMA. And the cost ranges from 120 to 160 units, with the average cost about 140, while the PMA scheme cost is very low, most of the cost value is around 100.

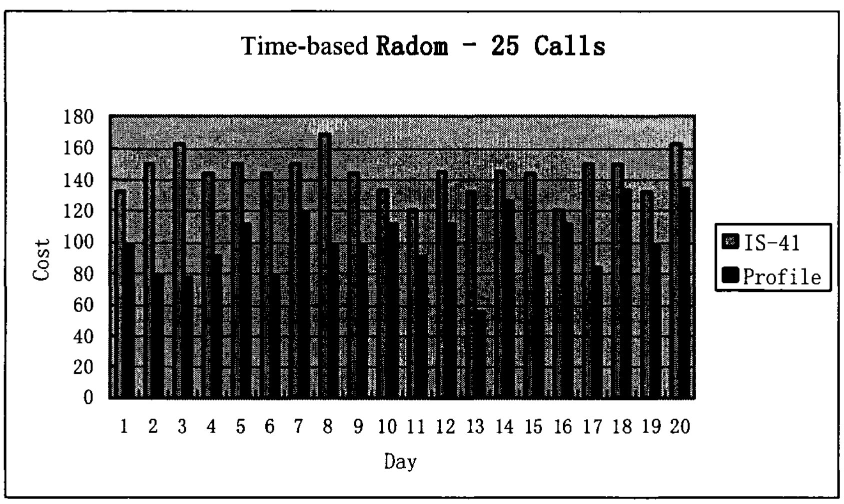


Figure 4-6: Relative cost for time-based random movement

2. Movement by Routine

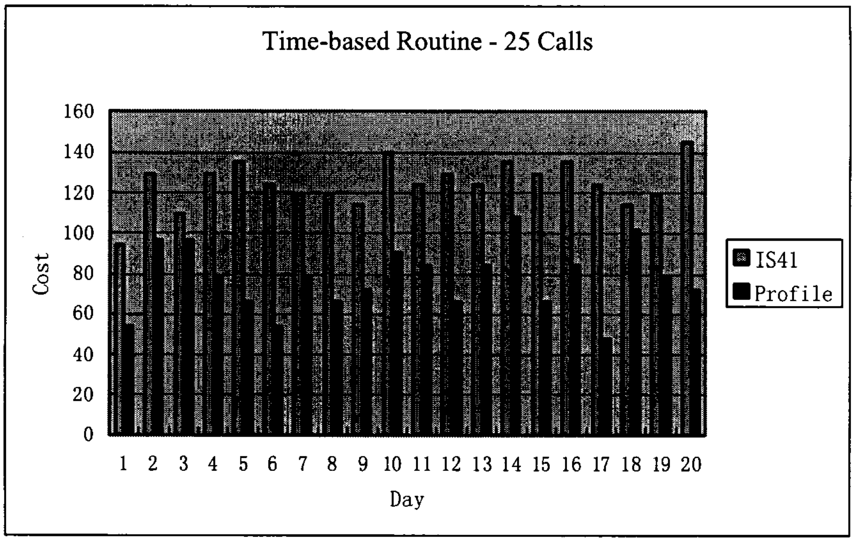


Figure 4-7: Relative cost for time-based routine movement

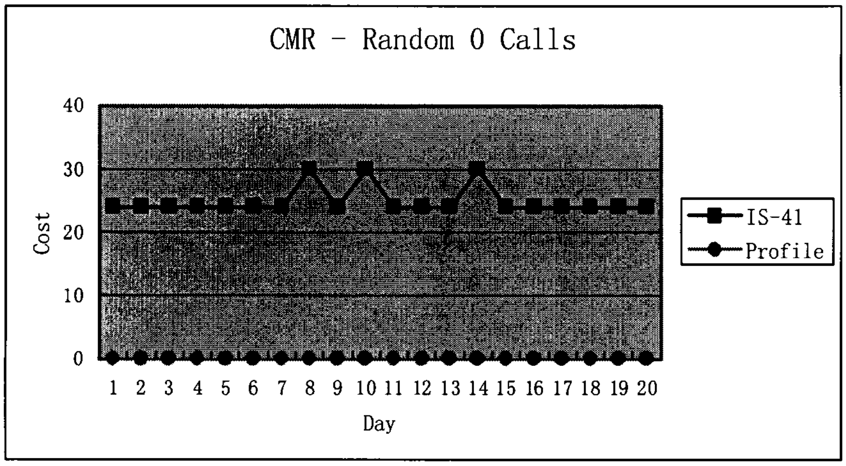
In figure 4-7, it shows that, in a routine way, when c is 25, IS-41 has the much higher cost than in PMA. And it ranges from 90 to 140 cost units, with the average cost is about 115, while the scheme PMA cost is very low, most of the cost value range around 60 to 70 units.

And from above observation we can say that, the routine-movement is better than random-movement at c is 25. In order to get the further proof for this conclusion, we will take many more values of c in the following simulations.

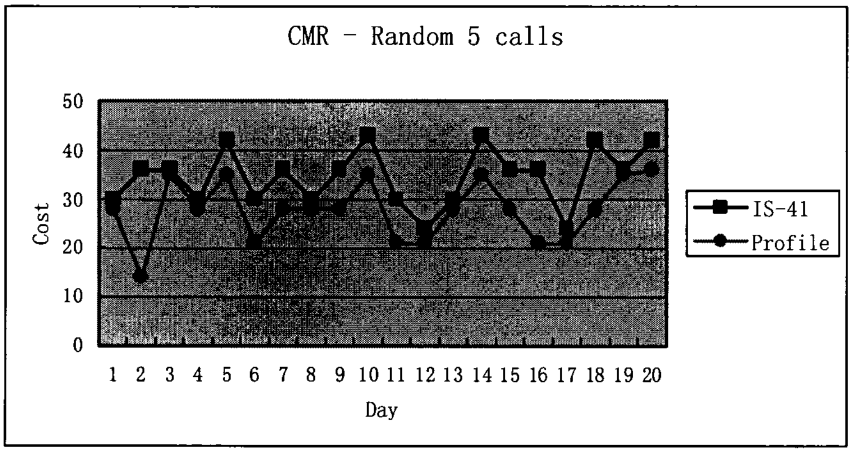
4.3.3. CMR-based (based on Incoming calls)

In most of the theory research, the CMR (Call-to-Mobility Ratio) is used to study the performance of the proposed scheme on cost reduce. In fact, the daily incoming call is in direct proportion to the Call to Mobile Ratio (CMR), that is to say, the more incoming calls, the higher CMR. And the number of the incoming call is decided to a large extent by a user's personal activities. It is unreasonable to use the parameter, the average number of the calls in each cell, to compare the cost. So here we use the number of the incoming call c, as our parameter of cost comparison.

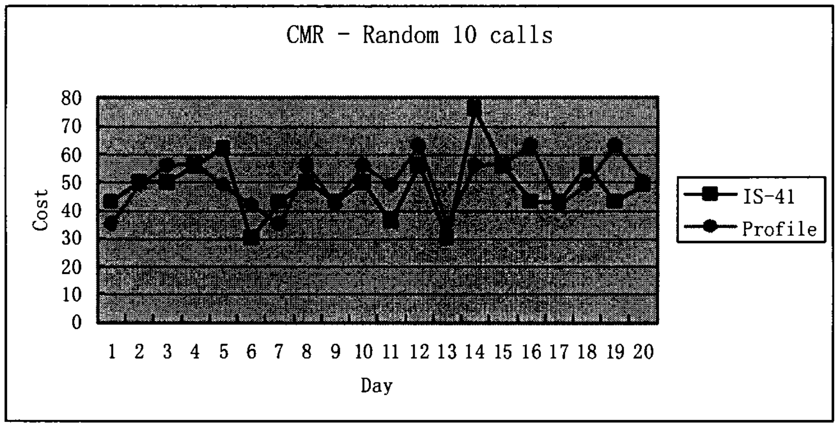
1. Movements by Random



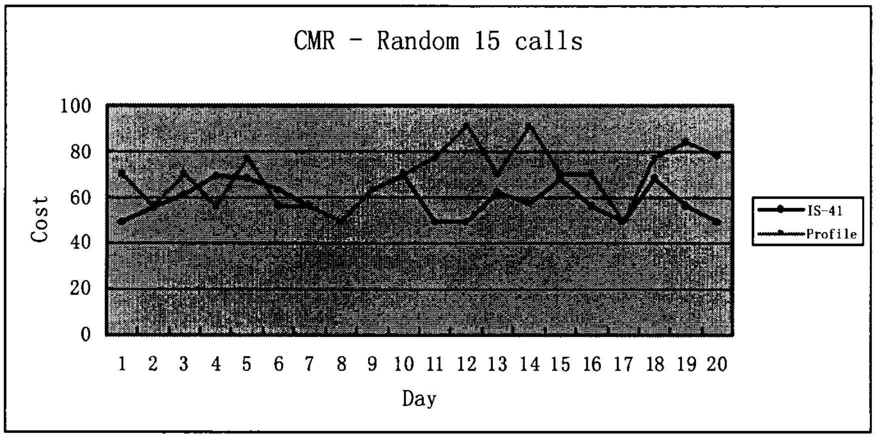
(a)



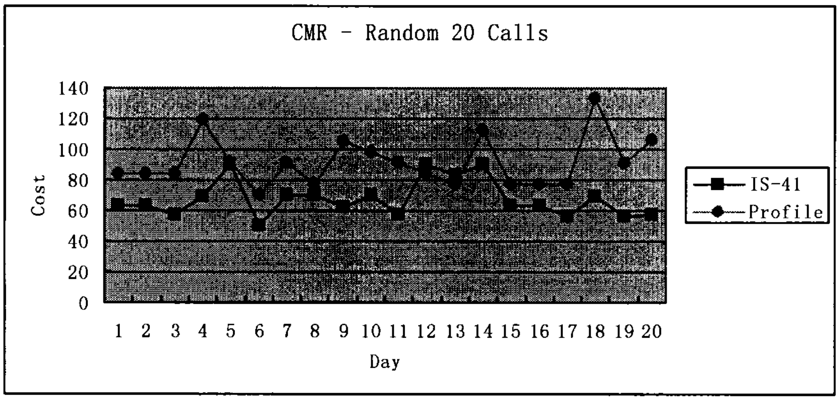
(b)


CMR - Random 10 calls
Cost
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

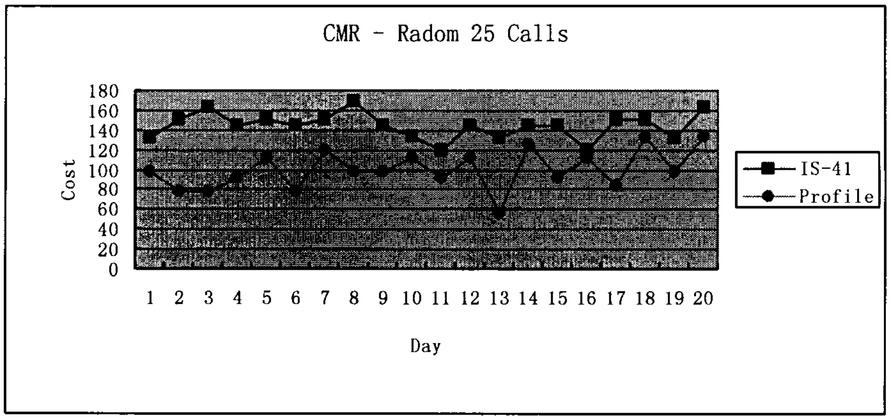
(c)


CMR - Random 15 calls
Cost
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

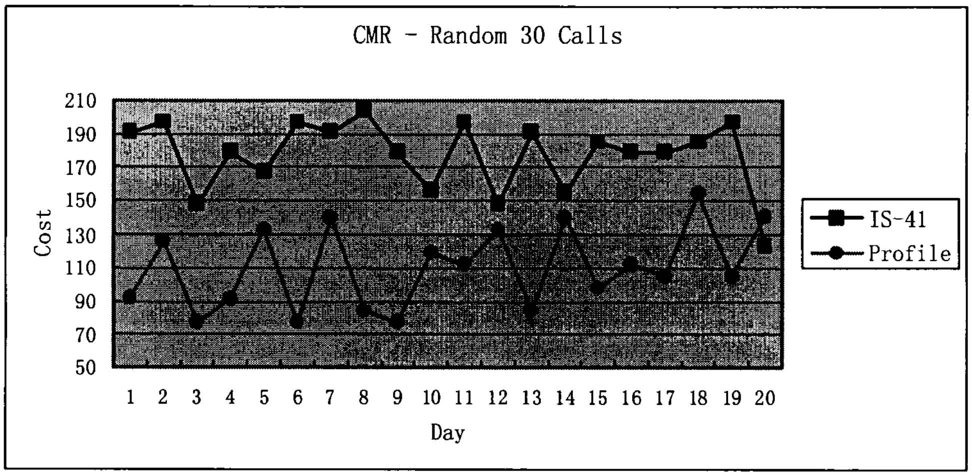
(d)


CMR - Random 20 Calls
Cost
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

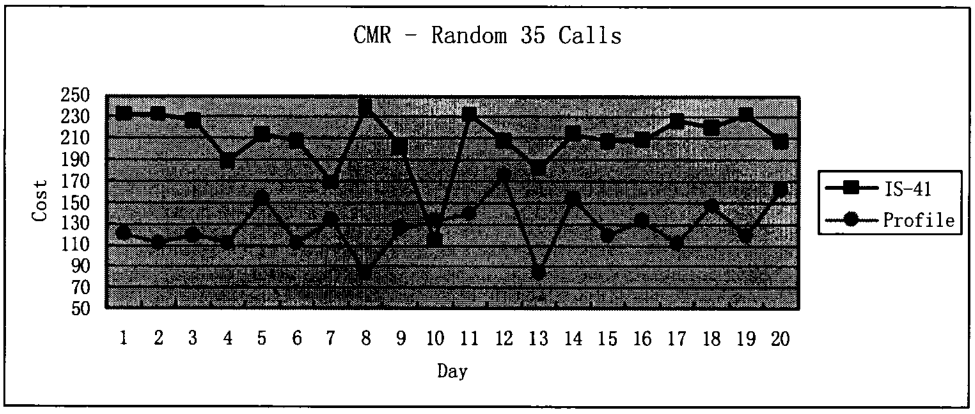
(e)


CMR - Radom 25 Calls
180
160
140
120
100
80
60
40
20
0
Cost
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

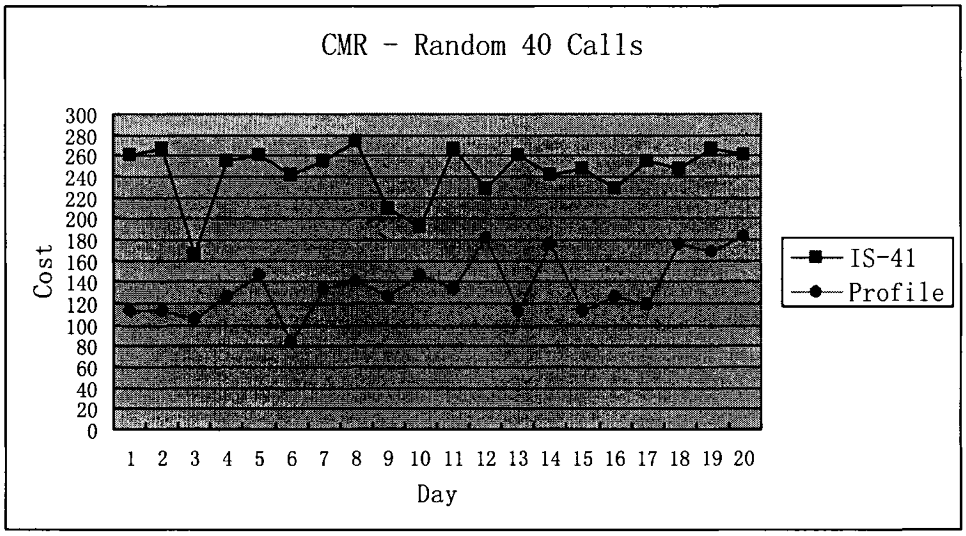
(f)


CMR - Random 30 Calls
210
190
170
150
130
110
90
70
50
Cost
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

(g)


CMR - Random 35 Calls
250
230
210
190
170
150
130
110
90
70
50
Cost
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

(h)



(i)

Figure 4-8: Relative cost with time-based random movement

In Figure 4-8, (a) - (i) shows the case of a mobile user moves by random and the incoming call is 0 - 40, respectively. Table 4-1 shows that the ranges of the relative cost for IS-41 and PMA scheme, at he model of time-based random movement, and with the above values of the incoming calls. The value of the cost is by cost unit.

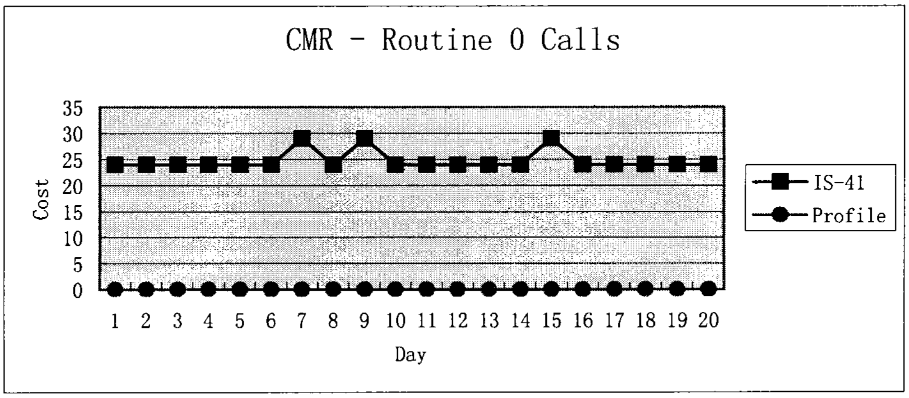
The figure 4-8 and Table 4-1 show that, along the c increase, the relative cost of PMA much less than the IS-41, for example, in Table 4-1, when c is 15, the cost of IS-41 ranges from 50 to 70 units, while PMA from 50 to 90. When c increase to 30, the cost of IS-41 rise to 150 – 200, while PMA costs only 70 – 150 units.

And it is obviously to see, in random movement model, the minimal total cost is attained when c = 0. In this case, the performance of our scheme performs absolutely great, while the IS-41 scheme still have some low cost. The reason is because that we don't do any location update and location search only happens when there is some incoming call. So when there is not any incoming call, the cost is always 0 with our scheme. However, this case rarely happens in normal life for a mobile user. Most of the mobile users have some daily calls, and with the increase of the incoming calls, IS-41 takes too much cost, while PMA will show a large benefit at this time.

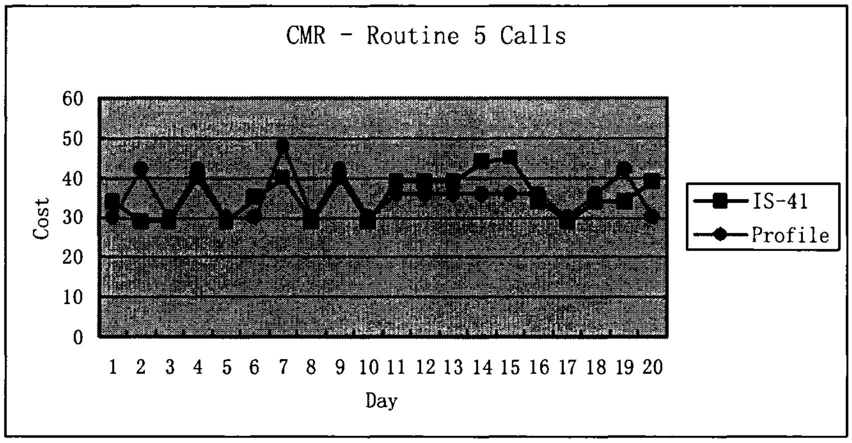
Table 4-1: Cost range of IS-41 and PMA in random movement

	IS-41	PMA
0	24 - 30	0
5	30 - 40	20 -30
10	50 - 60	30 – 60
15	50 - 70	50 -90
20	50 - 90	60 - 130
25	120 - 170	80 – 130
30	150 - 200	70 – 150
35	170 - 240	110 – 160
40	200 - 280	100 - 180

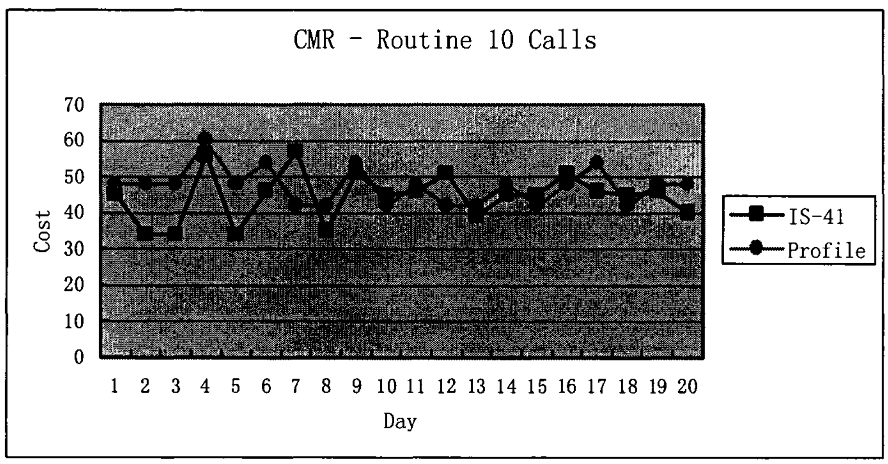
1. Movements by Routine



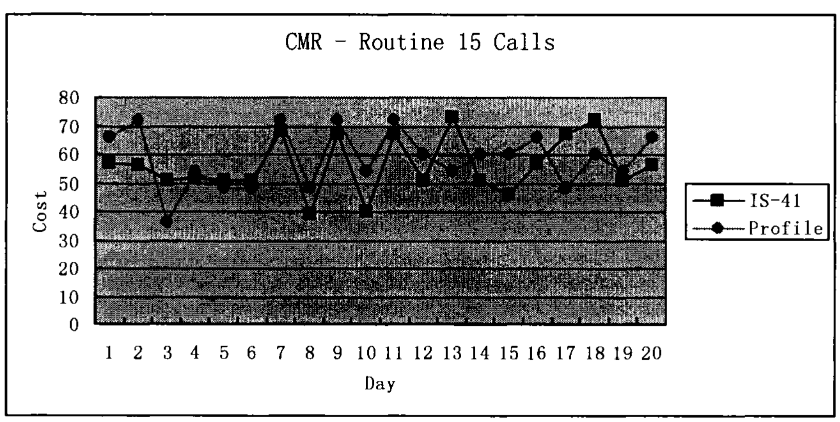
(a)


CMR - Routine 5 Calls
60
50
40
30
20
10
0
Cost
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

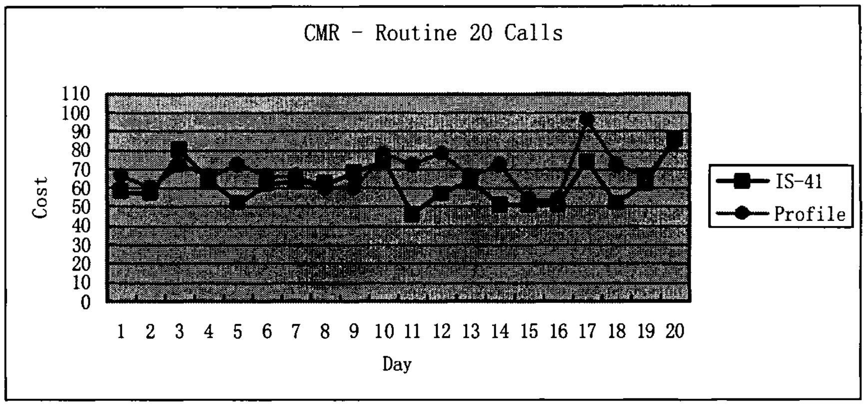
(b)


CMR - Routine 10 Calls
70
60
50
40
30
20
10
0
Cost
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

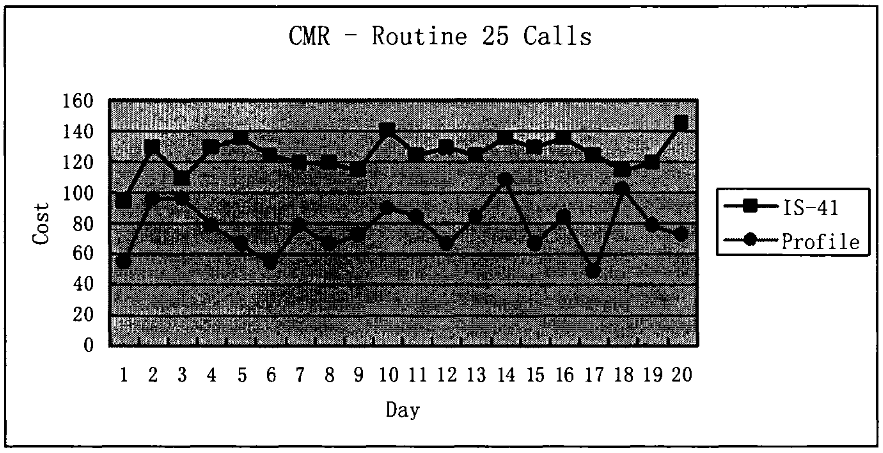
(c)


CMR - Routine 15 Calls
80
70
60
50
40
30
20
10
0
Cost
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

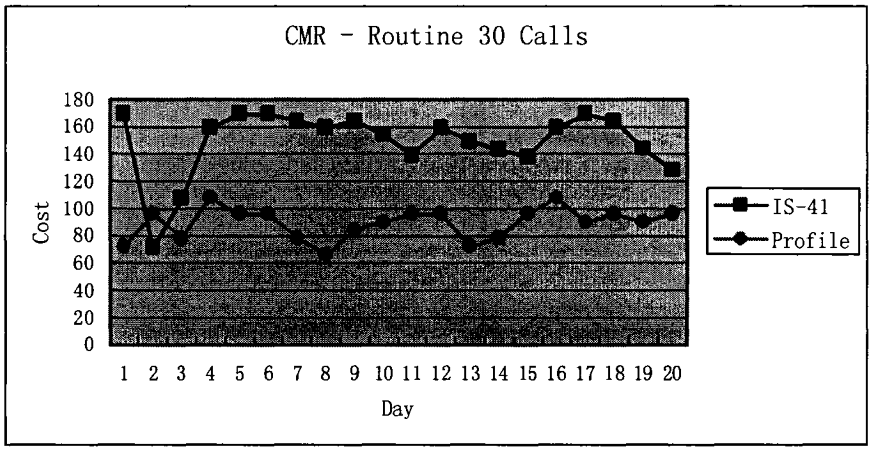
(d)


CMR - Routine 20 Calls
Cost
110
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

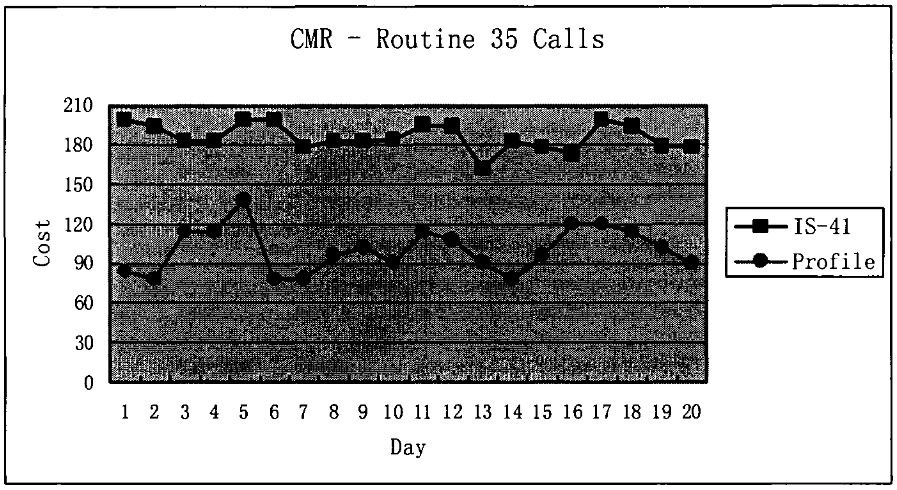
(e)


CMR - Routine 25 Calls
Cost
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

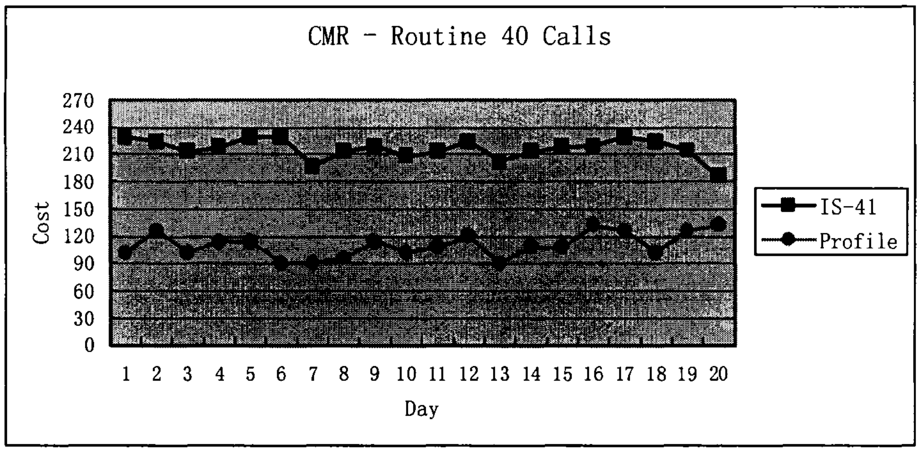
(f)


CMR - Routine 30 Calls
Cost
180
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Day
IS-41
Profile

(g)



(h)



(i)

Figure 4-9: Relative cost with time-base routine movement

Figure 4-9 (a) - (i) shows the case of a mobile user moves by routine and the incoming call is 0 - 40, respectively. Table 4-2 shows that the ranges of the relative cost of IS-41 and PMA scheme, at the model of time-based routine movement, and with the above values of the incoming calls.

From Figure 4-9 and Table 4-2, we can analyze the behavior of a mobile user with the routine movement that, it's similar to the situation of random movement. The relative cost of PMA is less than IS-41. And when the *c* increases, the cost the PMA is much less than in IS-41 scheme.

Relative cost is lower in routine movement than in random movements because in the case of random model, the handoff happen more frequently, and the probability to change cell location is very high, and the search missing occurs more, then location search and update increase.

So a conclusion comes out that in time-based model, the routine movement has the better performance than the random movement. That is the reason that we using the scheme PMA to trace and learning the mobile user' regular movement behavior. And then build the profile of the MU for the better performance of location management.

Table 4-2: Cost range of IS-41 and PMA with time-based routine movement

	IS-41	PMA
0	24 - 30	0
5	30 - 45	30 - 45
10	50 - 60	30 – 60
15	40 - 70	40 -60
20	40 - 80	50 - 80
25	100 - 140	50 – 110
30	100 - 170	60 – 110
35	160 - 210	80 – 140
40	180 - 240	90 - 130

4.3.4. Average Cost

Based on 20 days observation and trace, we obtain the daily average cost for PMA. See Figure 4-10. We build the profile in every 30 minutes, and obtain the cost according to the profile. It shows that the accuracy of the profile will have a great effect on the cost, the higher accuracy, the lower cost. If we can trace the MU for the profile every minute, the cost will be much lower. But we have to consider the cost to build, transmit and process the profile and database cannot also be ignored.

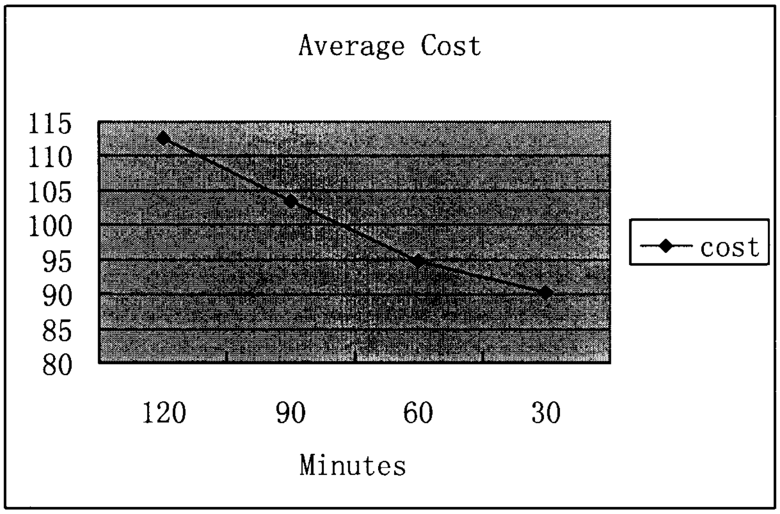


Figure 4-10: Average Cost of PMA

4.4 Summary

In this chapter, we investigated a mobile user's inter-cell movement behavior at network view, and time-based random and routine movement behavior at location management view.

In this model the location management is based on a user profile. Classifiable movement was modeled and formed to the profile which captures the regularity in a user's daily movement. To build the user profile, we proposed a learning algorithm good for tracing and recording the history movements of the mobile user in order to the future learning and use, namely PMA. Moreover, our method effectively reduced the total cost of location update and search significantly. It shown that with this method, reasonably accurate prediction can be achieved even when the system has no any incoming call. As a simulation model of the system implementation of PMA, an annalistic model was presented as a possible comparison to the standard IS-41 scheme, contributed for the predictive mobility management in wireless PCS networks.

The simulation results show that the proposed scheme PMA has the better performance than IS-41 scheme. And it also shows the PMA algorithm working correctly and efficiently.

Chapter 5
Conclusions

Mobile positioning and related user profiles supported control of wireless networks will become a key role in future network optimization and applications with upcoming location service. In our work, we describe a movement prediction scheme based on user profiles involving user movement history by using a predictive matrix algorithm, namely, the Predictive Matrix Algorithm.

With the learning-based prediction strategy, we improve the performance of location management in mobile networks. The PMA algorithm learns the user's movement history for obtaining the training data and structure, finally the profile of the mobile user aiming at the prediction of the future location.

The algorithm demonstrates a promising performance with the results obtained confirm the effectiveness of PMA in significantly reducing the costs of both location updates and call delivery procedures when compared to IS-41 and other well-known strategies in the literature.

In this chapter, we review the syntheses of work and contributions, limitations of research, and future research directions.

5.1 Syntheses of Work and Contributions

Firstly, we recount some of the location management schemes followed by the detailed discussion of the location update and search algorithms in 3G. A brief look at the novel location management scheme presented by us, namely, Predictive Matrix Algorithm (PMA).

Then a detailed description of the learning-based location prediction scheme, as well as a simulation model is present.

Finally, We give the analysis of our system. The goal is to obtain the evaluation of the performance. And we compare our PMA location management algorithms proposed here with posed before. Right through these discussions, we could see the advantages of our scheme compared with the IS-41 scheme.

5.2 Limitations of the Research

With the PMA learning method, we obtain the advantages on reducing the overhead of the signaling cost. But we still cannot ignore the limitation of the work.

There are two limitations in our works.

1. As we described in the chapter 3, the accuracy of the profile is has an affection on the performance of our scheme. That is to say, the more accuracy of the profile, the better performance. But the large accuracy will be a tradeoff with certain extra cost. The information of the profile needs to be efficiently collected, stored, updated, and disseminated. The high accuracy must go along with large data records, therefore, there is a need for us to raise the system capacity. With the data rising, the time of query to the database will cost much more, as well as the more calculation needed. What is the best criterion of the accuracy of the profile? We could not answer this for sure so far. This is a major limitation of our research.

2. The results show that the proposed scheme have good performance, but it works for an exist user with their movement history record. It needs a long-term observation and record to form this history. But for a new user, in the beginning, we don't have any record or history of his/her movement behavior to learn for us. It takes time to obtain and learn the training data to build a profile.

5.3 Future Research Directions

The learning-based location prediction strategy was proposed as a technique to reduce the cost of location updating. Its operation is based on the observation that most users follow regimented daily schedules that can be exploited to estimate their current location. If the system knows that at a given time the user is most likely to be in a certain location area, the system can maintain a list of likely locations in which a mobile user will move in turn. When a call arrives for a user, it is paged according to the list. With this scheme, location update is not required. The mobile user will be located accurately according to his user profile. So the accurate is an important fact in the scheme. The more accurate, the less cost. But for the reason that we still could not find the exact accuracy so far in our study. We still need to do a large number of experiments, studying and analyzing to find the very exact point of the accuracy for a good performance on location prediction.

For an existing mobile user, we can obtain and study his movements records for a long term, and then learn his behavior regular, finally build up the user profile for prediction. But for the new mobile user, we don't have any information on his movements behaviors. So that also is the other limitation. For the further research work, we will find a suitable method to set up dynamically the user profile in order to meet the needs for a new user without any record data for his/her movement behavior.

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